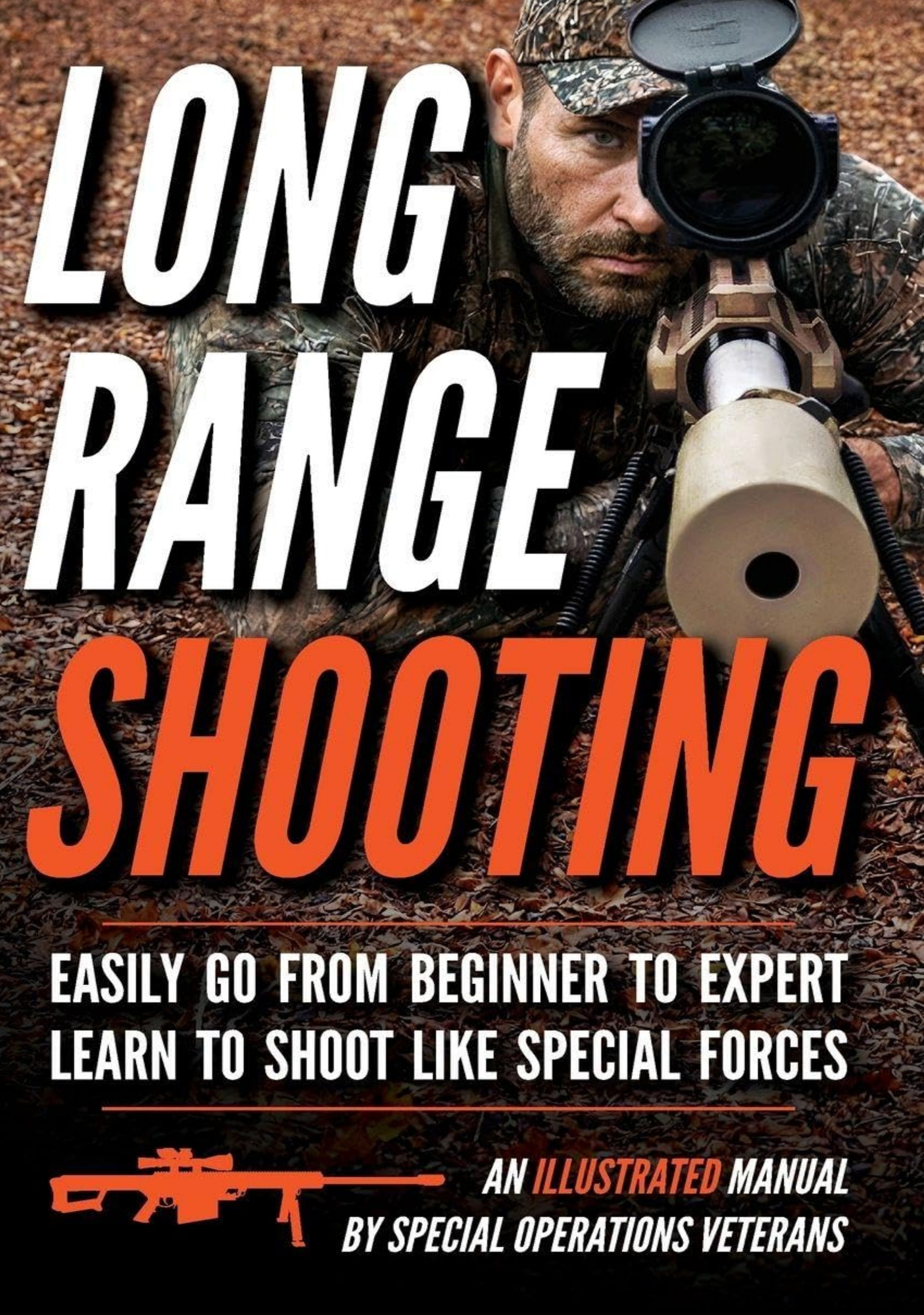

LONG RANGE SHOOTING

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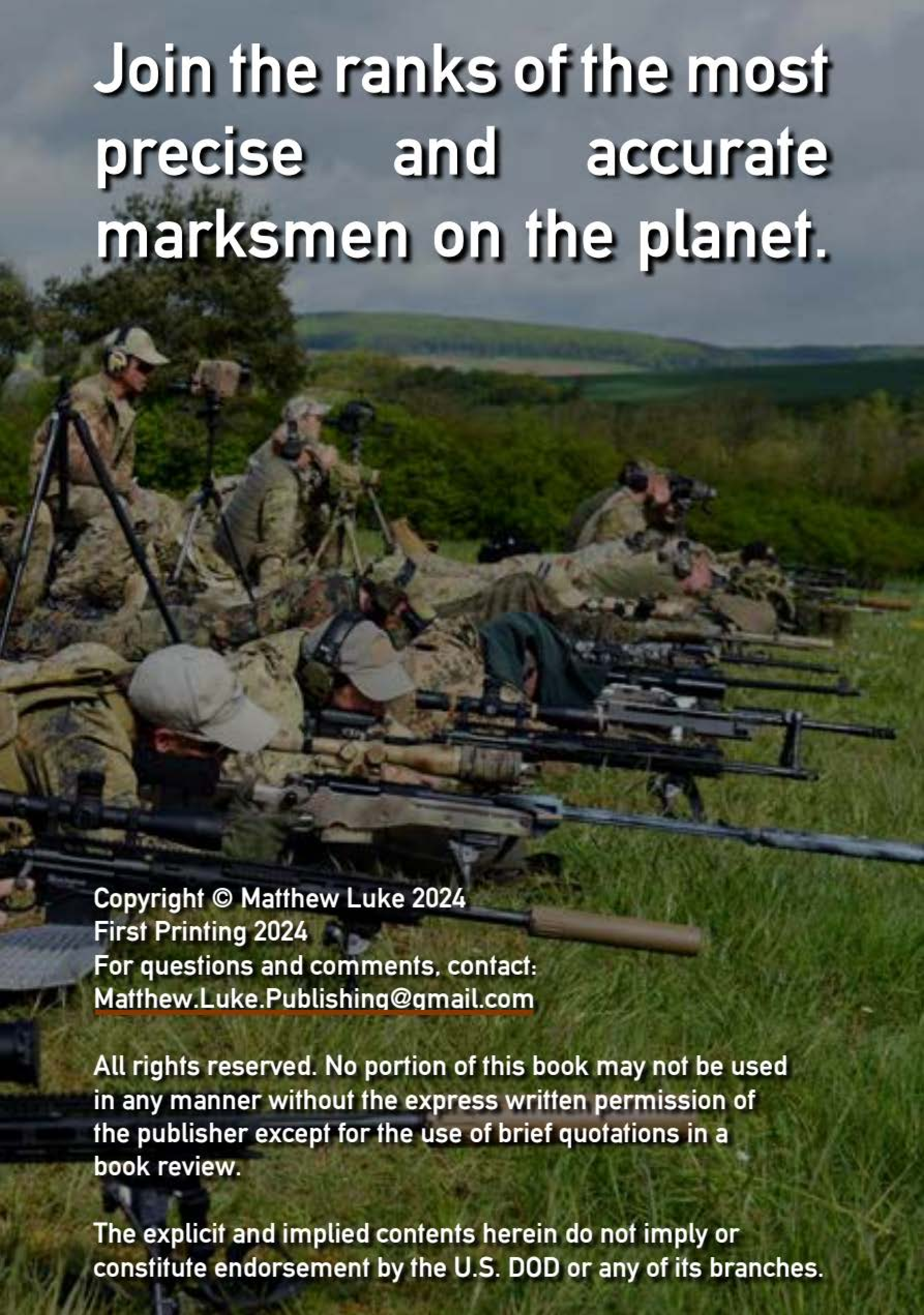

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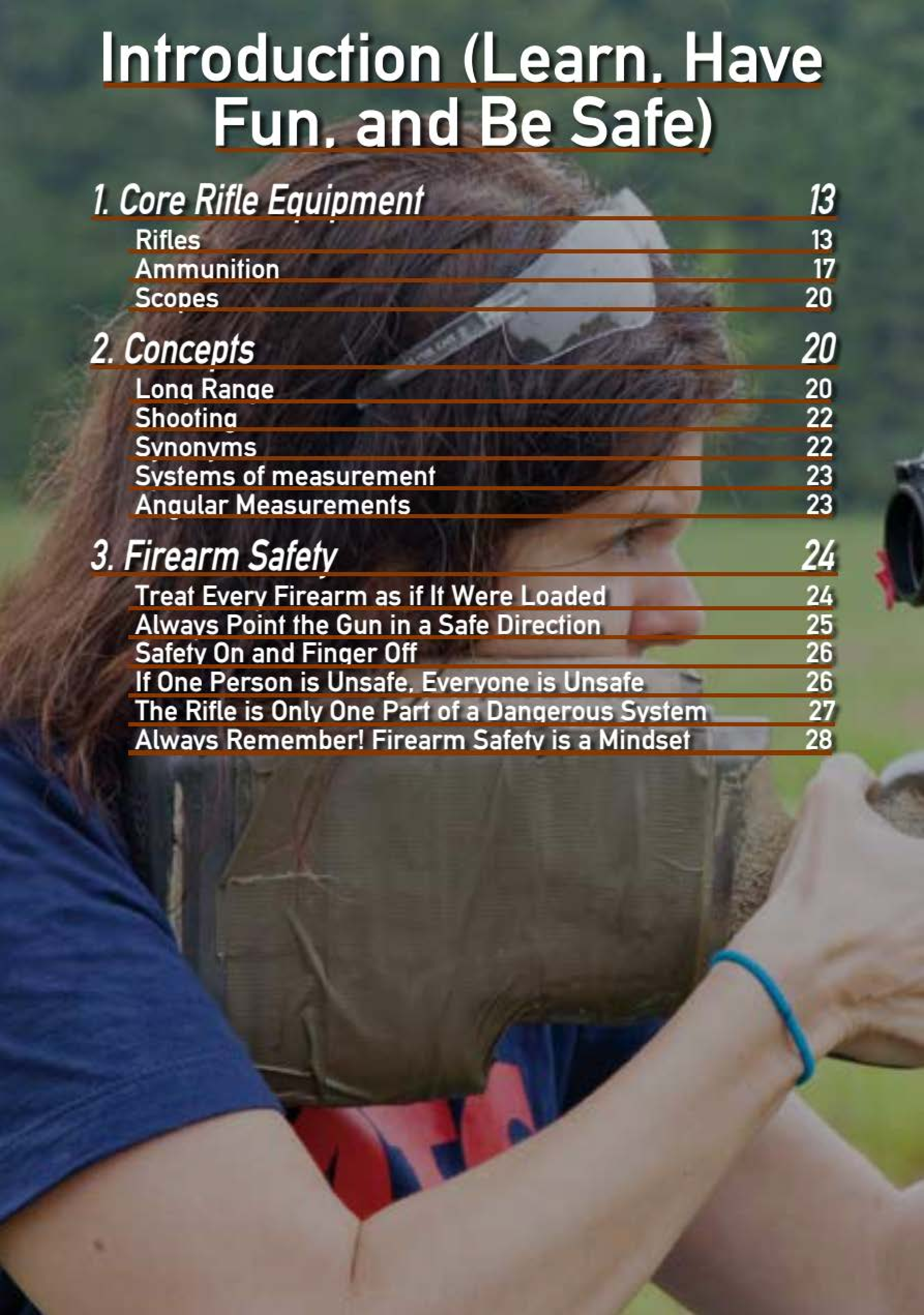

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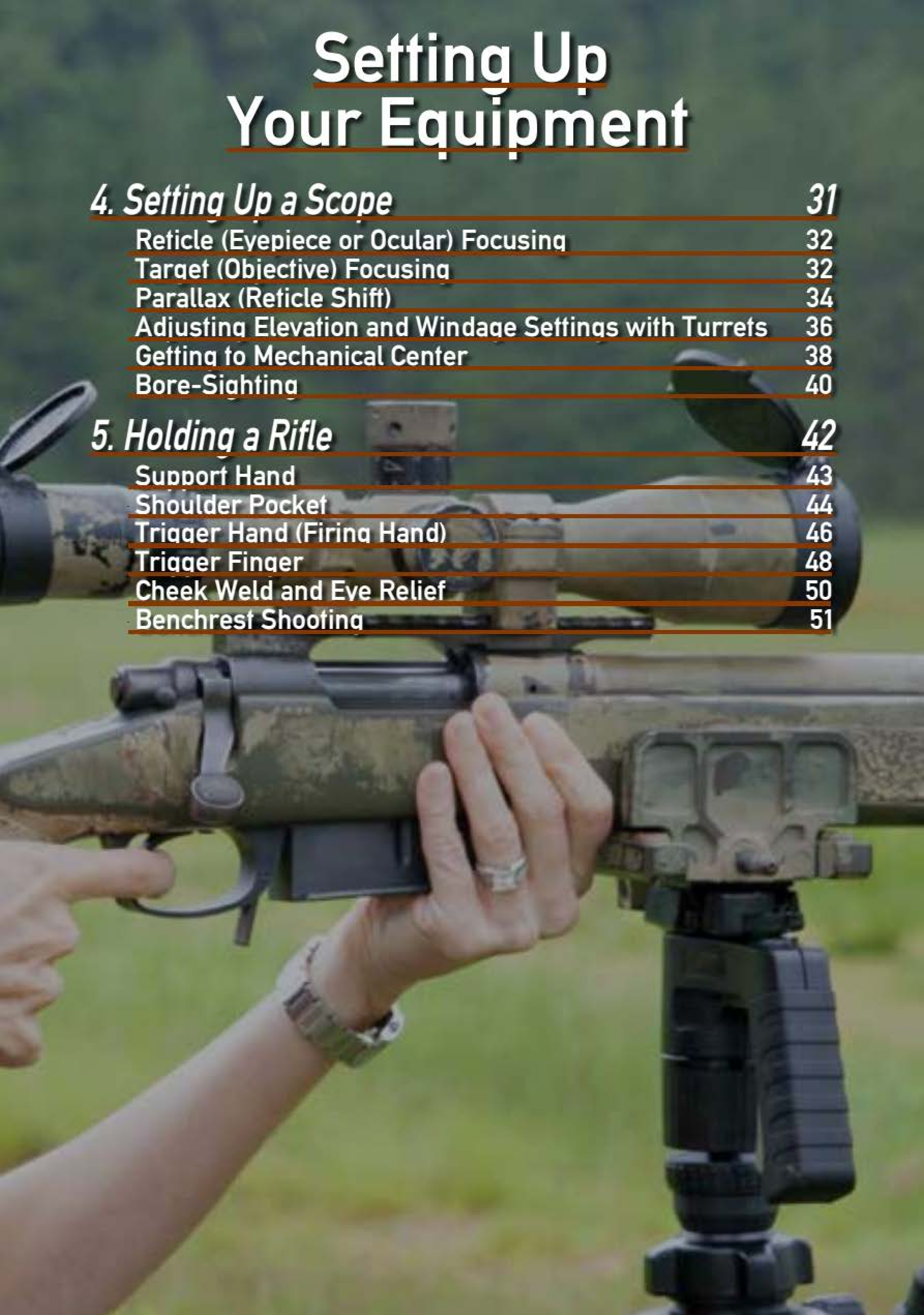

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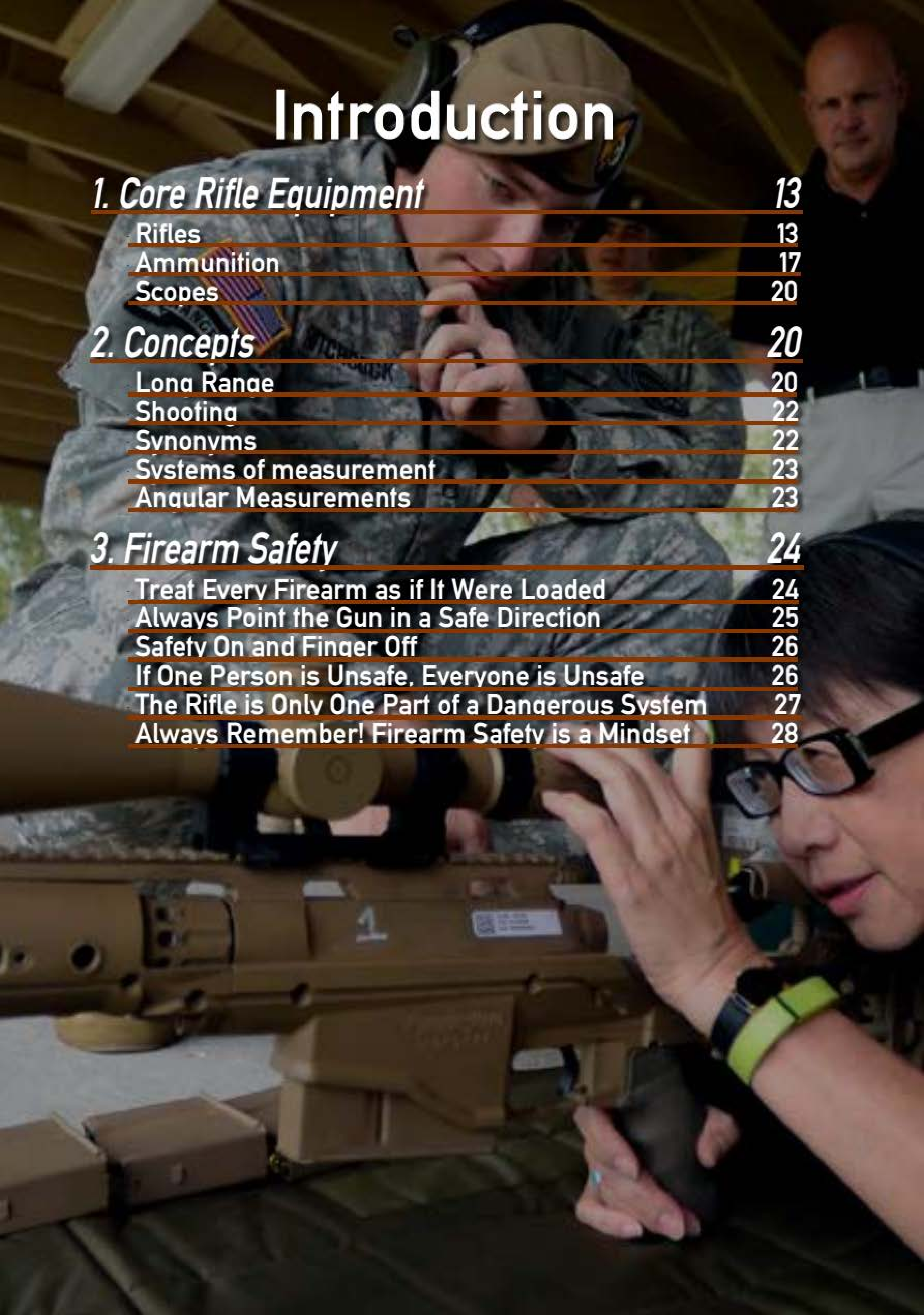

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Introduction (Learn, Have Fun, and Be Safe)

> *I have a very strict gun control policy: if there's a gun around, I want to be in control of it.*
>
> —*Clint Eastwood*

This manual uses **easy, step-by-step** explanations to teach you how to shoot and bring out the inner sniper that you were meant to be. After reading this book, you will find that you are way more precise and accurate than ever before, and you will be able to maximize the power of your rifle to the fullest. With enough time, you may even become as proficient as the most elite marksmen in the world: **United States Special Forces**.

Before explaining how to shoot, this introduction quickly covers rifle equipment, useful concepts, and firearm safety. This is to help first-timer marksmen or to refresh more experienced marksmen. If all of this is redundant, then readers can **skip to the next chapter.** (See Setting Up Your Equipment, Pg. 31.)

1. Core Rifle Equipment

This manual assumes that readers possess a **long-range rifle with ammunition and a scope.** These three core components along with the marksman themself comprise a weapon that can propel a bullet to wherever the marksman wants it to go. Additionally, a marksman may incorporate extra equipment that enhances precision and accuracy, such as ballistics calculators and weather meters.

1.a Rifles

A rifle is a weapon with a barrel from which a bullet (i.e., the projectile) is propelled by gunpowder (i.e., the propellant), and with a stock that transfers recoil into the marksman's shoulder through a stock. A rifle consists of five major components: the receiver, the barrel, the action, the trigger group, and the stock. (See Image 1, Pg. 14.)

The **receiver** "receives," or attaches to, all of the other components of the rifle and is the core hub of the rifle. This is not a hard definition, and sometimes it can be difficult to isolate a single receiver. For example, the

Rifle System Parts

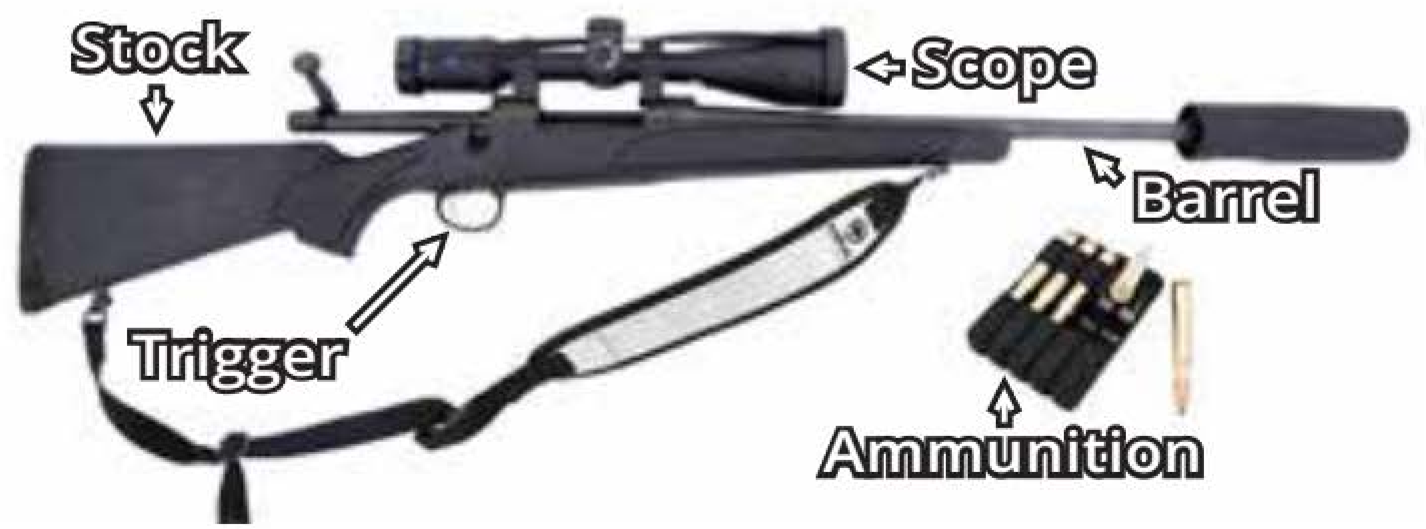


Image 1: Remington Model 700 in .30-06 Springfield. This is a **bolt-action rifle**, which means the marksman must themself move the handle behind the scope backwards to eject a fired round and forwards to load a new one after firing.

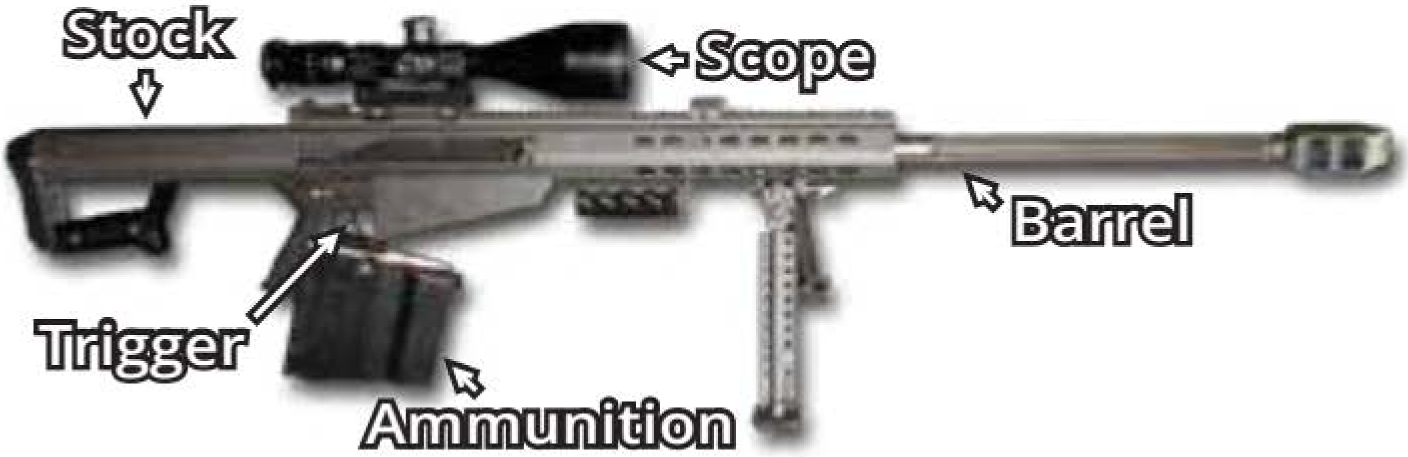


Image 2: A G82 German Army Barrett M107 variant. This is a **semi-automatic action and rifle**, and so one trigger squeeze only fires the rifle and automatically loads a new cartridge. A fully-automatic rifle would additionally fire that round and keep firing until the magazine were empty or the trigger were released.

U.S. Army's rifle, the M4, has two receivers: an upper and a lower. Both parts attach to other rifle parts and also to each other. (See Image 3, Pg. 15.)

The **barrel** is the metal tube that a bullet travels down. The inside of a barrel is called the "bore." Importantly to be a rifle, a long-gun's bore must have interior grooves, called "rifling," that both grip and spin the bullet. By spinning, bullets can use gyroscopic forces to keep their pointed tip facing forward causing less air resistance and farther, more precise travel. Barrels also keep the exploding gas inside so that it can press against the back of the bullet. The longer time that gas can act on the bullet, the faster a bullet travels, which is why longer barrels create more muzzle velocity than shorter barrels.

The **action** of a firearm refers to the combination of parts that facilitate the loading, firing, ejecting, and general mechanical action of ammunition. What parts of a firearm constitute the action differs depending on the rifle's

Rifle Receivers

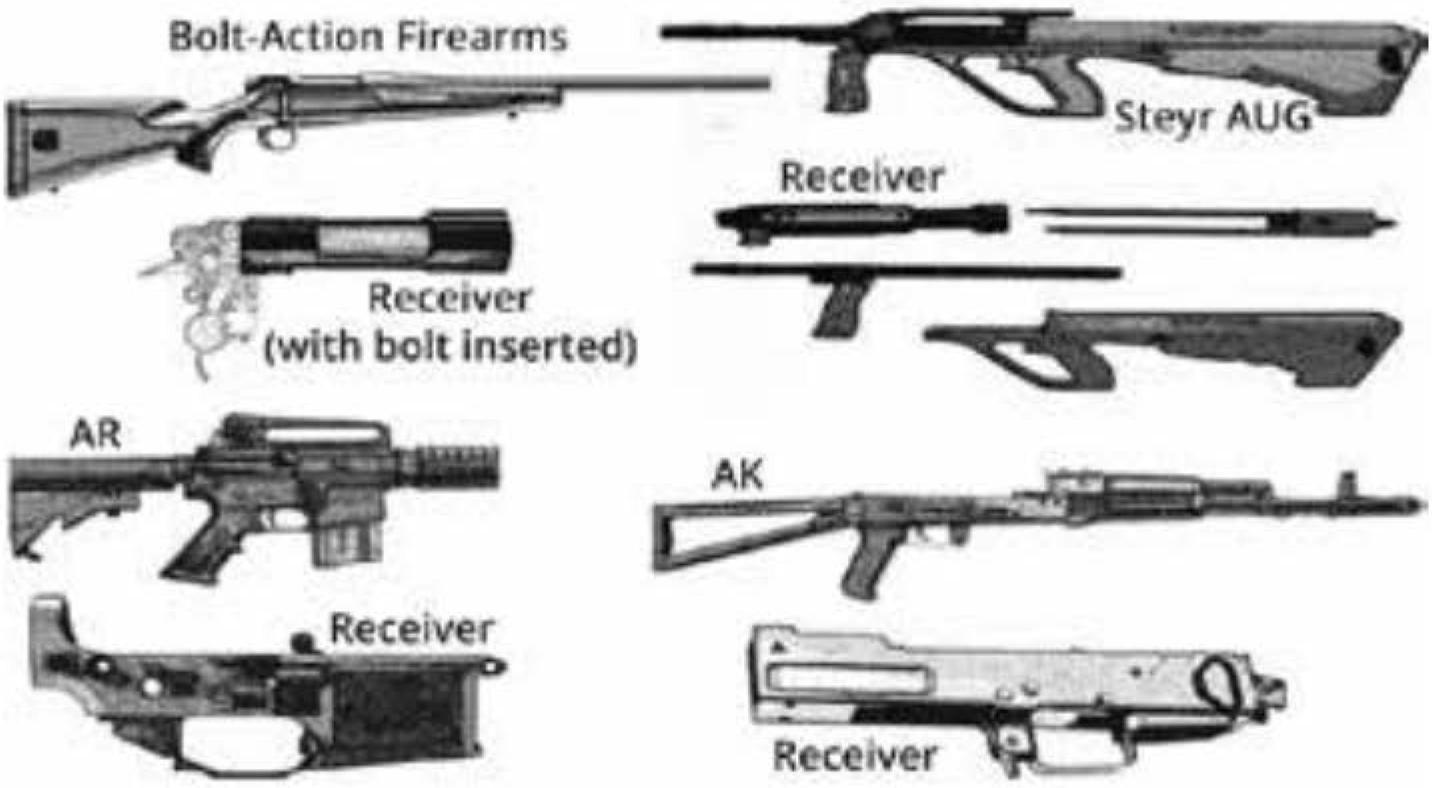


Image 3: Rifles come in many forms. The Bureau of Alcohol, Tobacco, and Firearms (ATF) is responsible for regulating, and therefore defining, firearms in the United States. Because a firearm can still discharge a bullet while missing parts such as the scope, the stock, and most of the barrel, the ATF (and thereby the U.S. Government) **defines a "firearm" as its receiver** (i.e., the central connection part). But defining what a receiver is exactly is difficult, so the ATF had to supply the four above images among many others to clarify with specific examples.

operating system and is sometimes debated. The location where a bullet is loaded into, ready to be fired, is called the **chamber**. Although the chamber is formed into the rear of the barrel, it is often considered part of the action, since it relates to the manipulation of the ammunition. To hold a round in the chamber, a metal cylinder called a **"bolt"** is placed behind the round. The bolt stays behind the round and locks the chamber while the bullet is fired. The bolt must be able to move and open the chamber up again to allow for the ejection of the spent round and the insertion of a new round. Bolts are also the rifle part that pushes a round into the chamber. (See Image 4, Pg. 16.)

There are two widely used actions in long-range shooting: manually operated actions and automatically operated actions. Manually operated actions require the marksman to manually reload a new round of ammunition after the trigger is pulled, whereas automatic actions automatically load the next round after firing using the force generated by the previous round firing. The most commonly used manual action in long-range shooting is the bolt-action. With this mechanism, the shooter pulls the bolt back to open the chamber and eject the spent round, then pushes it forward to load a new

Receiver Area

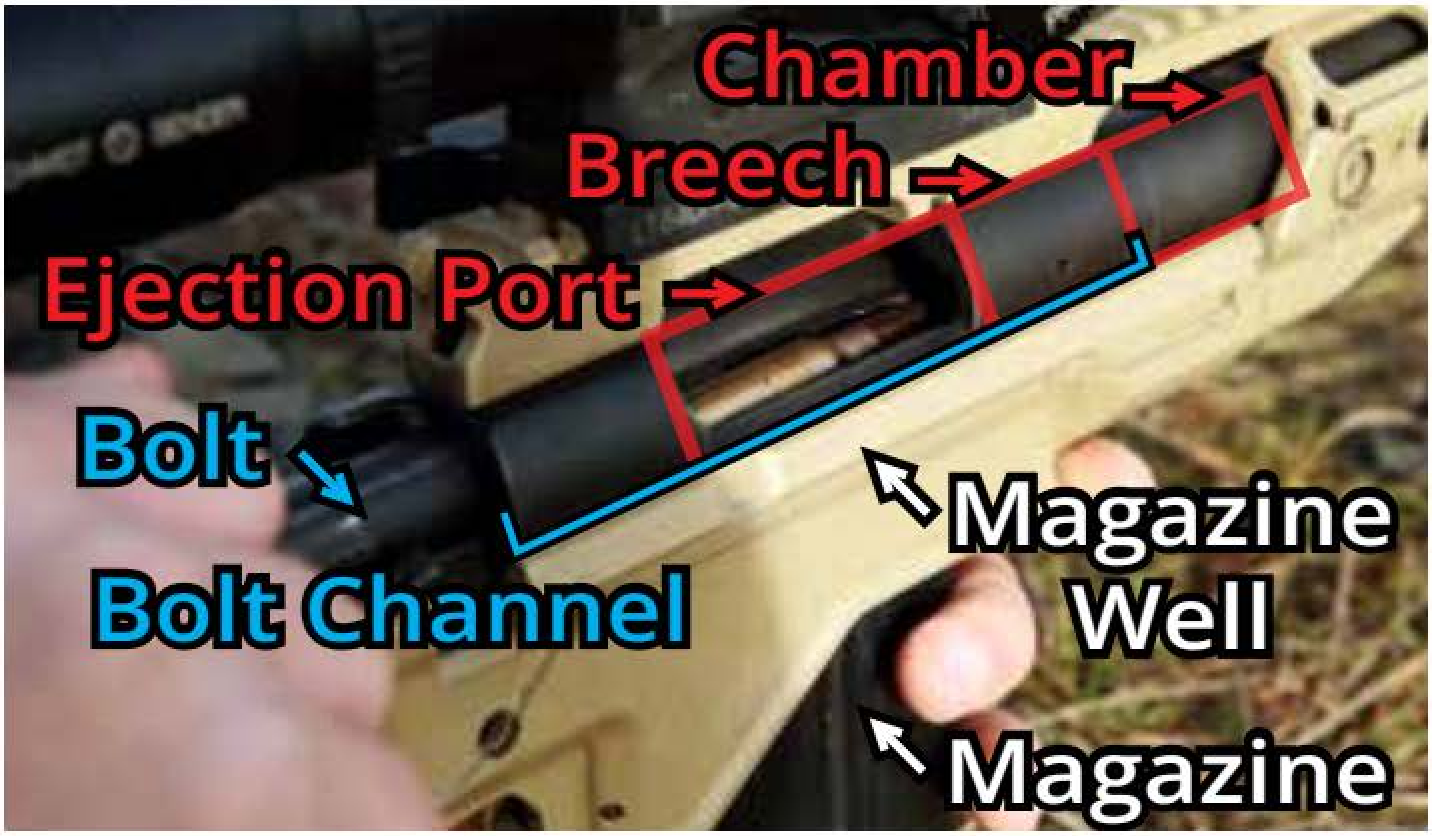


Image 4: The location of stored cartridges is the **magazine**. If the magazine is detachable, it is inserted into the **magazine well** located in the stock or receiver. The **bolt** is the metal cylinder that inserts, locks in, and ejects cartridges from the rifle. The part of the bolt that touches the back of a cartridge is the **bolt face** (not pictured). The bolt travels along the **bolt channel** to transport rounds from the magazine. The open part of the bolt channel is the **ejection port**. The forward, closed part of the bolt channel is the **breech** (a breech is an entryway for ammunition). After the bolt channel is the **chamber**, where ammunition is locked in, ready to be fired. (As with all vocabulary, definitions vary between sources.)

round and close the chamber. (See Image 1, Pg. 14.) There are a variety of automatic actions, but since the marksman does not interact with the mechanisms, their operation is not vital to the skill of shooting. The only important distinction to make is between fully automatic actions, which fire bullets as long as the trigger is depressed, and semi-automatics, which do not fire the bullet after loading it. All automatic actions intended for long-range shooting are semi-automatic. (See Image 2, Pg. 14.)

The **trigger** is the part of the rifle that the marksman operates to cause the gunpowder to explode. The trigger does not directly act on the ammunition, and instead is just the first in a chain of parts called the “trigger group” or “trigger assembly.” Around the trigger is a thin band of metal called the “trigger guard,” which helps to prevent any unintentional depressing of the trigger. The ideal trigger provides a constant level of resistance to being pulled back. A one-stage trigger has a single level of resistance. In contrast, a

Rifle Stock Terms

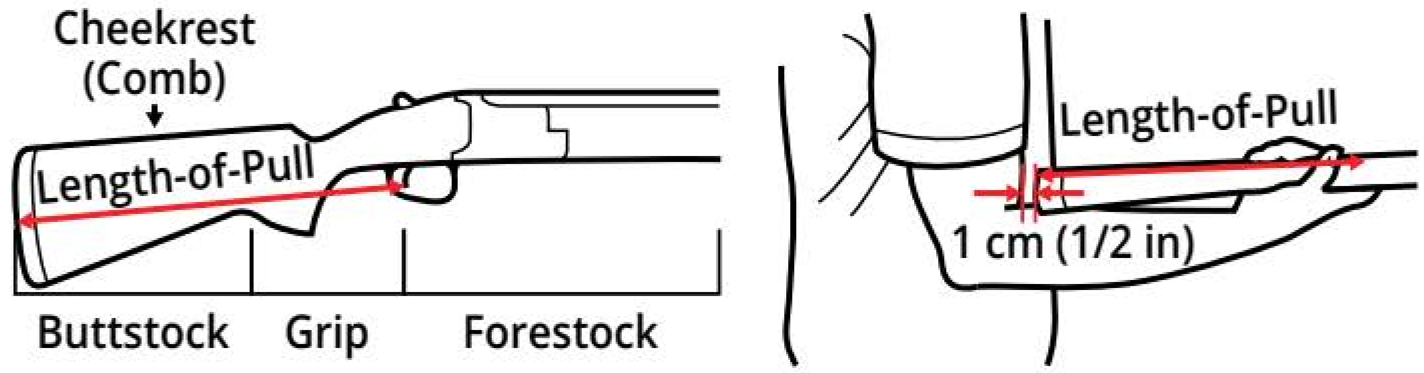


Image 5: Rifles can be customized to their marksman. The most important customization is the **length-of-pull**, which is the distance from the trigger to the buttstock. A length-of-pull that is too short prevents a marksman from properly placing the buttstock in the shoulder pocket. (See Shoulder Pocket, Pg. 44.), while one that is too long interferes with placing the check on the stock. (See Cheek Weld and Eye Relief, Pg. 50.) A proper length-of-pull leaves **1 cm (0.5 in)** of space between the stock and the biceps when the marksman's finger is in the trigger well and the arm is resting at **90 degrees**.

two-stage trigger suddenly increases the resistance level immediately before the trigger would fire the rifle, which can be a useful safety feature.

The **stock** is the part of the rifle that interfaces with the marksman's body. The shooting hand holds the grip, while the front hand holds the forestock. The rear of the stock, the buttstock, presses into the marksman's torso, and the marksman lays their check on the top of the buttstock, called the "cheekrest" or "comb." A properly fitted rifle stock has a correct **length-of-pull**, which is the distance from the trigger to the end of the buttstock. (See Image 5, Pg. 17.)

Rifles may also come with accessories that are helpful but not strictly necessary. For example, external supports such as bipods and tripods can vastly increase the stability of a rifle.

1.b Ammunition

Ammunition is the expendable part of a rifle setup. It consists of four parts: bullets, gunpowder, primers, and casing. Together, these four parts are called "cartridges" or "rounds." (See Image 6, Pg. 18.)

Bullets are small pieces of metal that are constructed to transfer energy created at the marksman's location to the target while facing the least amount of air resistance possible. To carry more energy, bullets are made of dense materials, such as lead, that have more mass per unit of volume. To be durable enough to survive being fired and impacting, the lead is coated in a

Cartridge Parts

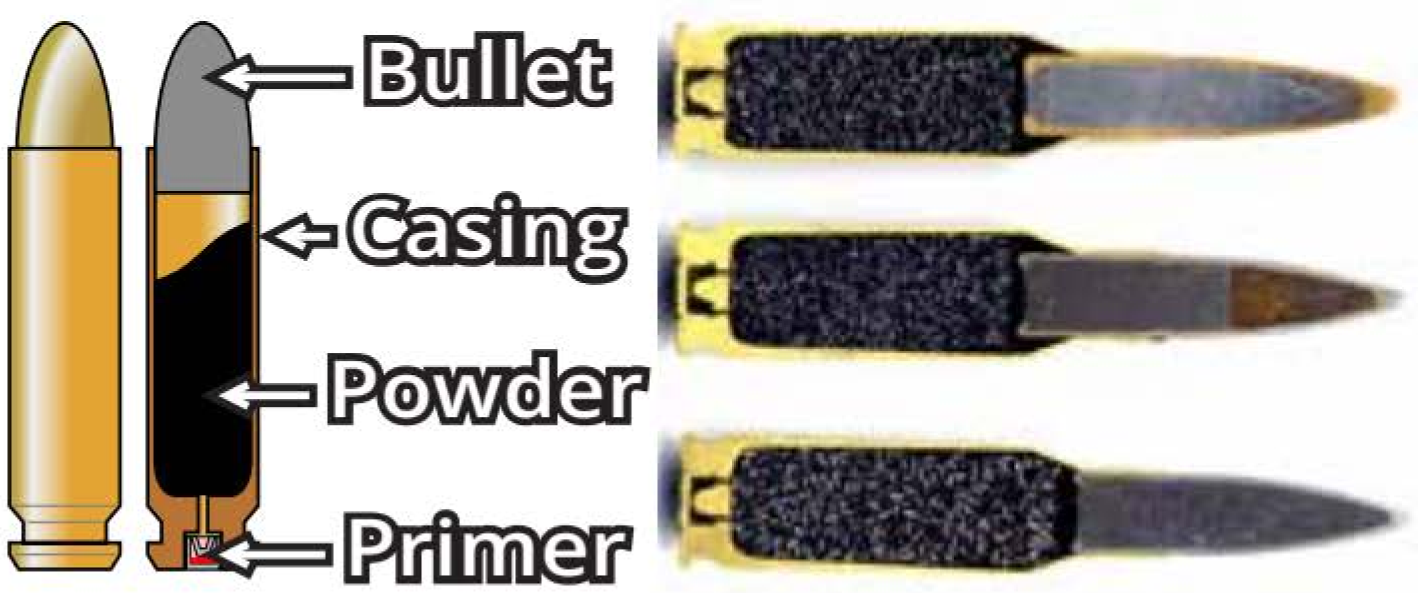


Image 6: A diagram of .280 / 30 British military sectioned cartridges. All widely used cartridges (a.k.a. rounds) use this structure. Note that identically shaped ammunition may be made with different materials and internal structures.

more durable material such as a copper alloy. And to reduce air resistance, bullets are made in a pointed shape that can slice through the air.

Gunpowder, or powder, is a solid material that causes a gas explosion. (Modern “powder” actually comes in pellet form.) The resultant gas explosion is always faster than the bullets it pushes since a slower gas cannot reach and push a faster bullet. However, while it is common to say that gunpowder “burns” or “explodes,” the technical term is “deflagrates” since the chemical reaction occurs slower than the speed of sound. (In a controlled environment, inside a firearm cartridge where pressure builds up rapidly, the effective speed of the expanding gases can result in projectile velocities of 500 to 1,200 m/s (1600 to 4000 ft/s) for rifles, but this is not the same as the actual deflagration rate of the powder itself.)

There are various gunpowder compositions that generate gases in a way that balances the power of the gases while minimizing damage that that power does to the barrel. This allows the gas to effectively propel the bullet without causing damage to the rifle.

Primers are small disks that explode when they are struck with a metal pin. That is, they are the interface between the mechanical energy release of the trigger and the chemical energy release of gunpowder. The pin they are struck by is called the “firing pin.”

Casings, or cases, are the metal cylinders that hold the bullets, the gunpowder, and the primers in place. Casings are most commonly made of brass, so they are often called the “brass”; however, casings can also be made of steel. They are made of metal because it is durable, but also because casings

Scope Turrets, Dials, and Reticles

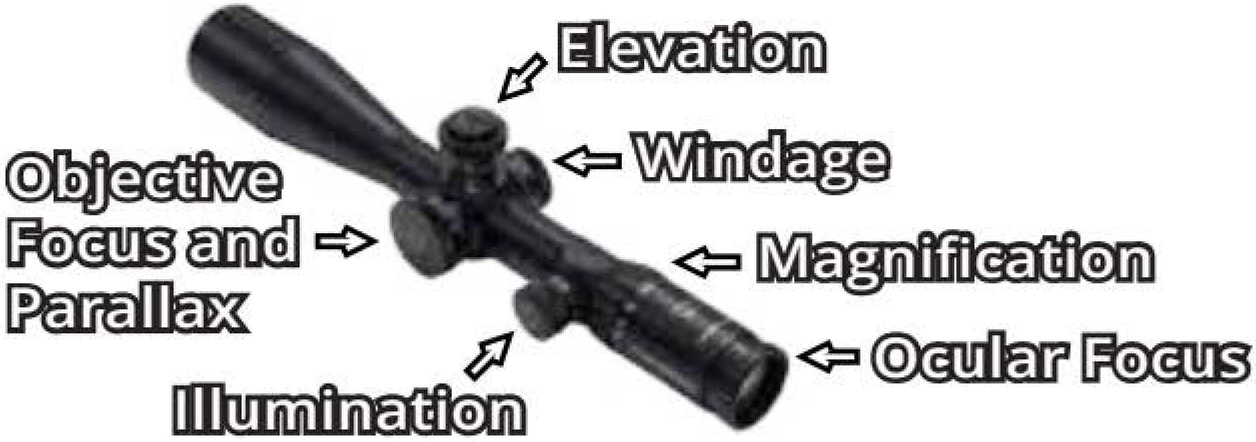

Elevation
Objective Focus and Parallax
Windage
Magnification
Ocular Focus
Illumination

Image 7: This Schmidt & Bender 5-25x56 riflescope has a parallax turret and an illumination turret on its left side.

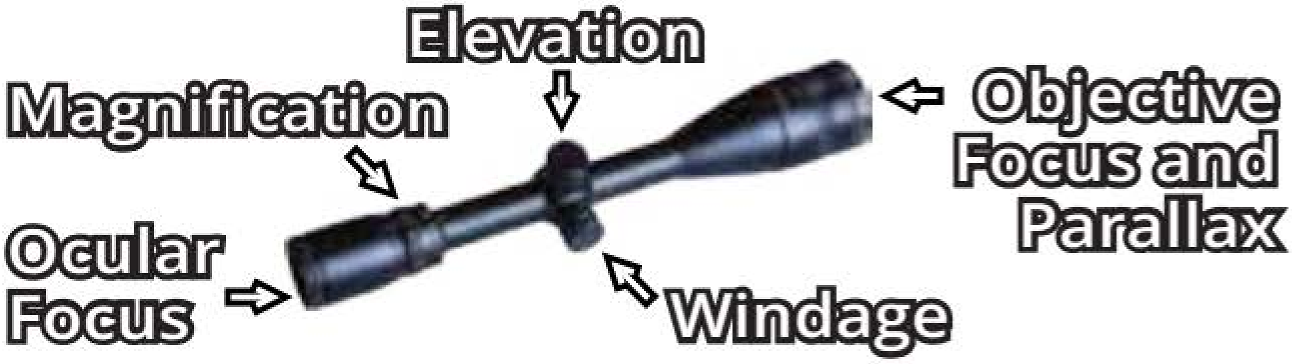
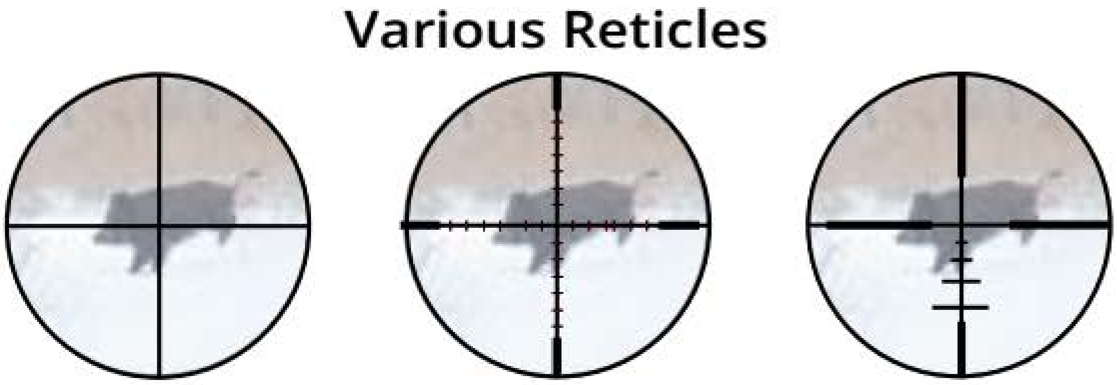

Elevation
Magnification
Objective Focus and Parallax
Ocular Focus
Windage

Image 8: This Swift 687M riflescope has a parallax dial on the objective bell (the forward end of a scope) and no illumination turret.


Various Reticles

Basic Crosshairs Mil-Dot Modern Rangefinding

Image 9: The sight picture is the image seen through the back of the scope by the marksman. The reticle is the pattern of hashmarks overlaid on the sight picture.

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serve to dissipate heat. When a hot casing is ejected from a rifle, the heat it carries can no longer be transferred to the rifle nor to subsequent rounds.

All normal, modern rifle store ammunition in the **magazine** (a.k.a. “mag”). Magazines can be an internal part of the rifle, or a detachable container. The location that detachable magazines are inserted into is called the “magazine well.” Magazines have internal springs that sequentially push each cartridge into a position where it may be readily loaded into the barrel chamber by the action.

1.c Scopes

A scope (a.k.a. riflescope or telescopic sight) is an optical attachment that is mounted atop a rifle. It is a kind of "**sight**," which is a tool that aids in aiming at a target. Scopes serve two purposes. First, they have internal markings on the lens that show a marksman where a bullet would impact if the rifle were fired. Second, they magnify the target to allow for better sight and more precise aiming. Long-range shooting usually requires a high-power scope ("high-power" means the lowest magnification setting is greater than one).

The internal markings on a scope's lens are called its "reticle." The **reticle** is a pattern of **hashmarks** (i.e., short lines or dots) that show where a bullet would impact if a bullet were fired. There are a variety of reticles that are explained more in-depth later in the book. (See Standard Reticles, Pg. 132.) Reticles can be adjusted up and down with the **elevation turret or dial**, and left and right with the **windage turret or dial**. (See Image 17, Pg. 37.)

Many scopes also have a **parallax turret or dial** on their left side that simultaneously changes the scope's depth-of-field (See Image 41, Pg. 62.) and parallax (See Image 16, Pg. 35.). Depth-of-field is the range of distance that is in focus for the marksman when looking through the scope. Parallax (as far as shooting is concerned) is the ability of the reticle to stay on the same point on a target even if the marksman moves their eye around the scope. Finally to focus the sight picture, a marksman can adjust the scope's eyepiece lens by rotating the eyepiece dial. (See Image 28, Pg. 49.)

2. Concepts

The following concepts are relevant to the rest of the content in this manual. Additionally, there is a glossary of terms included in the appendix at the back of this manual that contains terms which may not be familiar to all readers.

2.a Long Range

Long-range shooting involves using a rifle to hit a target at a significantly long distance. If pressed for a concrete number, a commonly used definition of "long range" is anything 300 m or yd or beyond. If more fineness is desired, "long range" can be defined differently for various rifle sizes. For example, a small rifle may have a "long range" of 100 m or yd, while a sniper rifle may have one of 500 m or yd.

The problem is that the term "long" can be ambiguous because marksmen generally associate the term with skill level and not actual distance. That

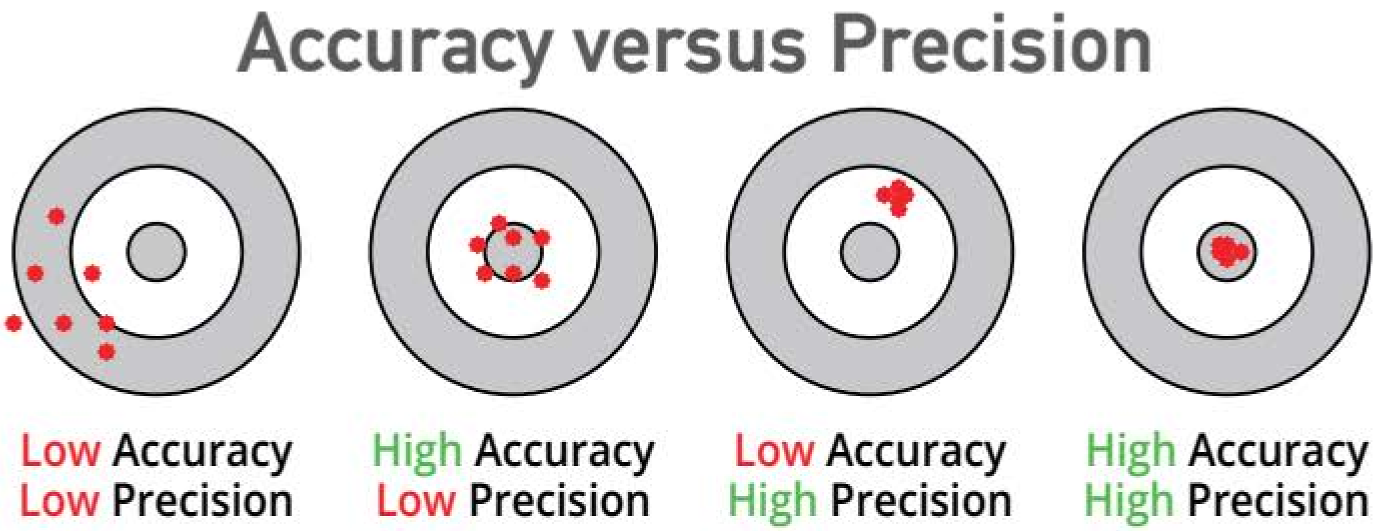


Image 10: Accuracy requires the skill of understanding the relationship between where a rifle is pointing and where a bullet would impact. Precision requires the skill of being consistent for every shot taken.

---

is, if a target is difficult to hit, then the target is perceived as being "far." Therefore, a more nuanced and perhaps natural approach to defining "long range" is based on the importance of **accuracy versus precision**. Accuracy and precision are two distinct-but-related concepts, and each requires its own skill set. (See Image 10, Pg. 21.)

Accuracy refers to a marksman's ability to **center the average** of all of their shots on the target. To be accurate, the bullet must be pointed at the target. That is, a marksman must have consistent and reliable equipment setups, such as securely aligned scopes. And the marksman must properly account for wind and gravity.

Precision refers to the ability to repeatedly hit a **small area** no matter where the center of that area is. To be precise, each successive shot must be fired under the same conditions as the previous shot. That is, a marksman must have consistent and accurate shooting techniques, such as consistently pulling the trigger in the same manner.

"Long range" is then the distance at which **properly aiming (accuracy) becomes more challenging than maintaining consistent shooting techniques (precision)**. In practical terms, if a bullet travels relatively flat up to 200 m or yd, aiming is simple because it only requires putting the target in the scope's crosshairs. However, if a bullet were to travel 1,000 m or yd in high winds, it would deviate significantly from a straight line and require calculations to find the correct aiming point and timing.

(Mathematically speaking, this shift occurs because environmental factors such as wind continue to affect a bullet throughout its flight, resulting in a small but exponentially increasing effect on the bullet trajectory. On the other hand, the marksman's influence has a significant effect only while the bullet is in the bore, resulting in a large but linear effect. Over time, the exponential effect caused by environmental factors always surpasses the linear effect caused by the marksman, with an exponent greater than one.)

2.b Shooting

The goal of shooting is to propel a small mass at high speeds toward a specific target. The skill of shooting comprises the numerous acts required to achieve that goal. This manual covers approximately fifty distinct topics related to long-range shooting that range from using the correct posture to hitting targets at vastly different elevations.

It is important to note that not all of these skills are necessary for every marksman. For example, an indoor target marksman and a military sniper both shoot at long range, but the former is far more concerned with equipment while the latter is more concerned with wind. As a result, while the definition of what constitutes the goal of "shooting" is clear, the skills that comprise "shooting" are subjective based on each marksman's particular needs and situation.

In particular, many people object to the idea that one can be a marksman if they do not perform certain acts or skills because they associate the term "shooting" more with the acts and skills rather than the goal. This is relevant to modern technology, which removes much of the work that was previously required to propel a small mass at high speeds toward a specific target. For example, mechanical servos and cameras can allow a rifle to be fired from a location detached from the marksman, removing the need for the marksman to be still and stable.

While the traditionalist view is understandable, today's reality is that electronically assisted shooting systems are becoming increasingly accurate and widespread, with ballistic calculators being almost universally used. Therefore, this manual takes the stance that **"shooting" is based on the goal, which is to propel a small mass at high speeds toward a specific target.** Nevertheless, the information herein assumes that a reader does not always have electronic assistance so as to provide the most comprehensive instructions possible.

2.c Synonyms

If this book uses a term unfamiliar to a reader, it may simply be because the reader uses another term for the same thing, and not because the object or concept itself is something new. Many times **multiple words have come**

to identify the same concept because traditionally, rifles and guns have been a very decentralized activity. For example, "dial, turret, or knob" are all interchangeable; the front end of a stock is known as the "forearm," "fore-end," "forend," "handguard," "forestock" and more; and the front attachment to a barrel that lessens the sound of firing is called the "silencer," "suppressor," or "sound moderator." This issue is especially prevalent when discussing how bullets move in the air. (See Image 111, Pg. 129.)

2.d Systems of measurement

There are two main systems of measurement used in the world of shooting, the **metric system** (formally known as the "international system of units (SI)") and the **imperial system** (formally known as the "United States Customary System"). Ballistic charts, scopes, and other shooting accessories often use metric units for easier and more precise adjustments. However, it is common for United States civilians to still use the imperial system.

Therefore, this manual presents both systems, usually starting with metric units followed by imperial unit within parentheses (e.g. 100 m (109 yd)). Metric units are first because metric is currently the global standard among militaries, including the United States, and it is slowly becoming the global standard for manufacturers as well. More about these units is explained in the appendices. (See Linear Distance, Pg. 235.)

There are some measures and units that are specific to the world of rifles and shooting that are uncommon elsewhere. For example, a common measure is **caliber (cal)**, which is the internal diameter or bore of a gun barrel. Caliber can be presented in either inches (e.g., 0.45 cal is 0.45 in) or millimeters (e.g., 9 mm). A common imperial unit that is specific to shooting is the **grain**, which is 1/7000 of a pound. Because using such a fine unit of measure was convenient for weighing out gunpowder and bullet metal, grains were the international standard for ammunition-related weights even in metric-centric countries. That is, however, slowly changing as countries move to using grams and milligrams.

2.e Angular Measurements

Understanding angular measurements is vital to understanding how to properly use a scope. In brief, angles are important in shooting because many elements, such as scopes and marksmen, rotate about their axis. The point-of-origin (e.g., a marksman) forms imaginary lines with a starting point (e.g., the point-of-aim) and an ending point (e.g., the point-of-impact). The angle between these two lines can be measured. The two standard systems of measurement for angles are **minutes-of-angle (MOA) and milliradians (mils)**. There are 21,600 MOA in a circle and 6,283 mils in a circle. Approximately 3.5 MOA is equivalent to 1 mil. (The conversion is approximate not only for simplicity but also because the actual definitions of the units are not always clear).

With that said, **if there is any uncertainty on what an angular measurement is, readers may benefit from reviewing that information in the appendix at the end of this manual**. (See Angular Distance, Pg. 237.)

3. Firearm Safety

Firearms are extremely dangerous tools, and if misused, they can cause catastrophic injury or death. Therefore, nothing is more important than practicing safety precautions when handling a firearm of any kind by anyone. That is why every responsible firearm owner must prioritize safety, and why this long-range shooting manual begins with a chapter on firearm safety. (Please note that some of the terms in this section may not be familiar to those who have never shot before, but are clarified throughout the book in their relevant sections.)

3.a Treat Every Firearm as if It Were Loaded

No matter how experienced a marksman may be, it is crucial to handle every firearm as if it were loaded and ready to fire. Specifically, **firearms are never pointed at something that is not intended to be shot**. Disregarding safety precautions with flippant statements such as “Don’t worry, the safety is on” or “It’s not even loaded” is unacceptable in any setting. Many innocent lives have been lost due to misplaced confidence in the status of a firearm. It is not impolite or unwelcome to ask someone to reclear their firearm (even if they insist it is already clear). Always remember, it’s the supposedly “unloaded gun” that causes a negligent discharge.

To ensure a firearm is unloaded, the marksman must perform a “dry firing” process using the following steps: First, point the firearm in a safe direction where no one can be harmed in case of a discharge. Remember to keep all fingers away from the trigger guard. Next, remove the magazine if it is detachable and place it away from the firearm. Then, manually cycle the action of the firearm a few times to clear any remaining ammunition in the chamber. Visually inspect the chamber. Pull the trigger to attempt

RANGE SAFETY RULES
1. TREAT ALL WEAPONS AS IF THEY ARE LOADED AT ALL TIMES.
2. NEVER LET YOUR MUZZLE COVER ANYTHING YOU ARE NOT WILLING TO DESTROY.
3. KEEP A STRAIGHT TRIGGER FINGER UNTIL YOUR SIGHTS ARE ON TARGET.
4. BE SURE OF YOUR TARGET, ITS FOREGROUND AND ITS BACKGROUND.
5. ANYONE CAN CALL A CEASE FIRE AT ANYTIME.

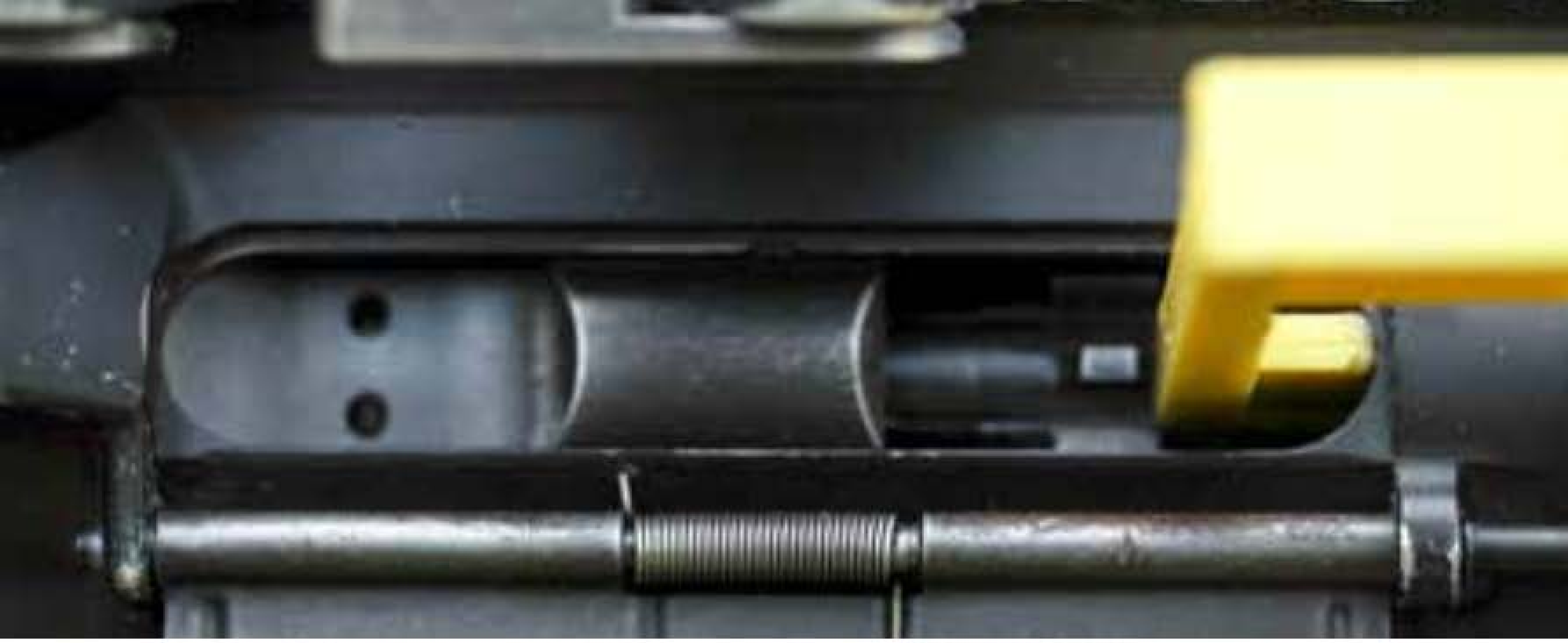
Image 11: No one is too cool or too skilled to forgo range safety.

to fire the firearm. Ideally, this is a "dry" fire because no ammunition was present in the firearm. Finally, it is recommended to keep the action open and visually inspect the chamber to ensure it is empty. Even after following these steps, the firearm must still be treated with the same extreme caution as if it were loaded.

3.b Always Point the Gun in a Safe Direction

Even if a firearm is loaded, it can only cause harm if it is aimed at someone or if they are close enough to be affected by the hot gases escaping the muzzle. For this reason, a marksman must only aim at things they are willing to shoot, such as a safe target or a location where a negligent or accidental discharge could not cause harm to anyone. Importantly, a safe direction always ends with a target in sight, and is never the air or somewhere far away where there is an unknown impact zone.

Examples of safe discharge locations include soft areas of the ground, a hill or berm, a target at a range. Although not ideal, if a marksman needs a safe indoors location, joists at where the wall meets the floor can stop most rounds.



Using a Chamber Flag

Image 12: When a rifle is not in use, a yellow or orange piece of plastic called a "safety flag," "breech flag" or "**chamber flag**" is inserted into the chamber to prove that a round cannot be in the chamber.

When navigating among firearms and marksmen, people must have the situational awareness to not walk in front of a rifle pointed in a safe direction, thereby rendering the direction unsafe. **To reiterate, awareness of one's surroundings and fellow marksmen is crucial when firearms are present.**

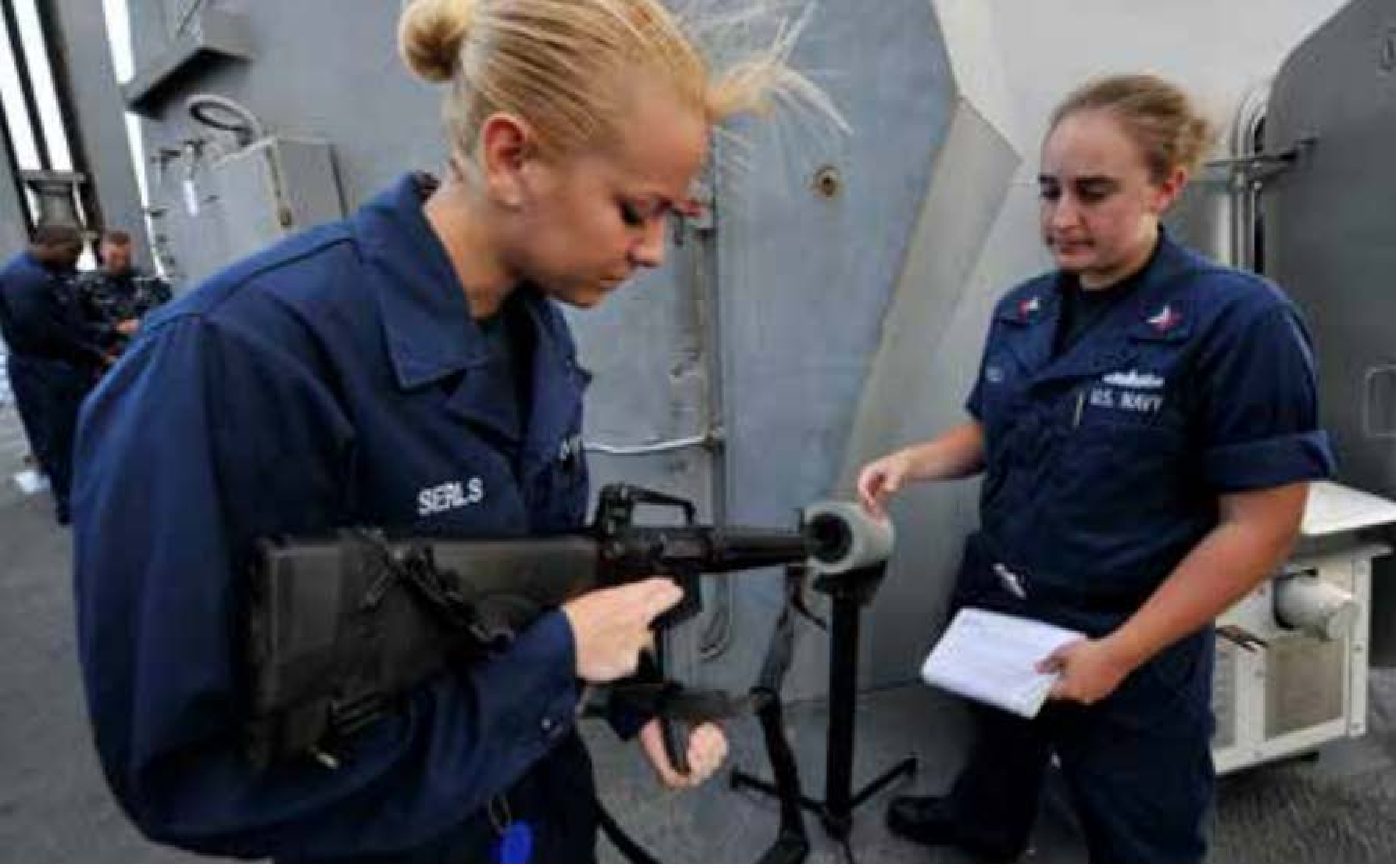
3.c Safety On and Finger Off

Even if a firearm is loaded and pointed at another person, it cannot be fired as long as the safety is on and the marksman's finger is off the trigger and outside the trigger guard. While keeping the index finger on the stock may feel unnatural and using the safety may seem inconvenient at first, these safety precautions eventually become habitual and cannot be disregarded.

Properly using the safety mechanism is one of the best precautions to take, but it must never replace the proper handling of a firearm as all the precautions are redundant, not interchangeable. For example, if there is no potential target, the rifle and magazine must not be loaded in the first place.

3.d If One Person is Unsafe, Everyone is Unsafe

Again, firearm safety is the responsibility of everyone. When firearms are being handed between individuals, trust and responsible handling cannot be assumed. During such instances, **both parties** must ensure that the action is open and the firearm is not loaded.



Using a Clearing Chamber

Image 13: A Gunner's Mate 2nd Class instructs a Sonar Technician (Surface) Seaman in clearing procedures for an M16 rifle. USS Jason Dunham (DDG 109), Gulf of Aden, 16 Nov 2012. The muzzle is pointed in a safe direction (into a purpose-built clearing chamber), her fingers are off the trigger, and she has **removed the source of the ammunition feed (i.e., the magazine held in her left hand).**

Making negative comments or bullying someone for safely handling their firearm is completely inappropriate. On the other hand, responsible marksmen must be willing to politely but firmly call out any safety violations, even if the other marksman is a stranger. Similarly, if a ceasefire is called for any reason, all marksmen must immediately comply by keeping their firearm pointed downrange, unloading it, and inserting a breech flag, sometimes also called a safety flag or chamber flag.

3.e The Rifle is Only One Part of a Dangerous System

Acting improperly when firing a rifle is just one way to cause damage with rifles. Messing with individual rifle parts is also dangerous. For example, when stripping or disassembling a rifle with a spring, it is crucial to be aware that springs are often under high pressure and that there is a potential for the spring to release its pent-up energy and cause injury.

A marksman must also consider that acts apart from firing can cause issues during a shooting session. For example, tiny rifle parts that are easy to lose can cause problems because marksmen may reassemble a rifle without knowing that particular part is missing. Therefore, **all cleaning and repair activities must be approached with the same level of care as shooting the firearm**. That means always attempting to clear the rifle of any ammunition and keeping the rifle's components orderly and separate from one another. If a piece is lost, the marksman must contact a professional because the accidental interchanging of parts can result in malfunctions or serious harm while operating the weapon.

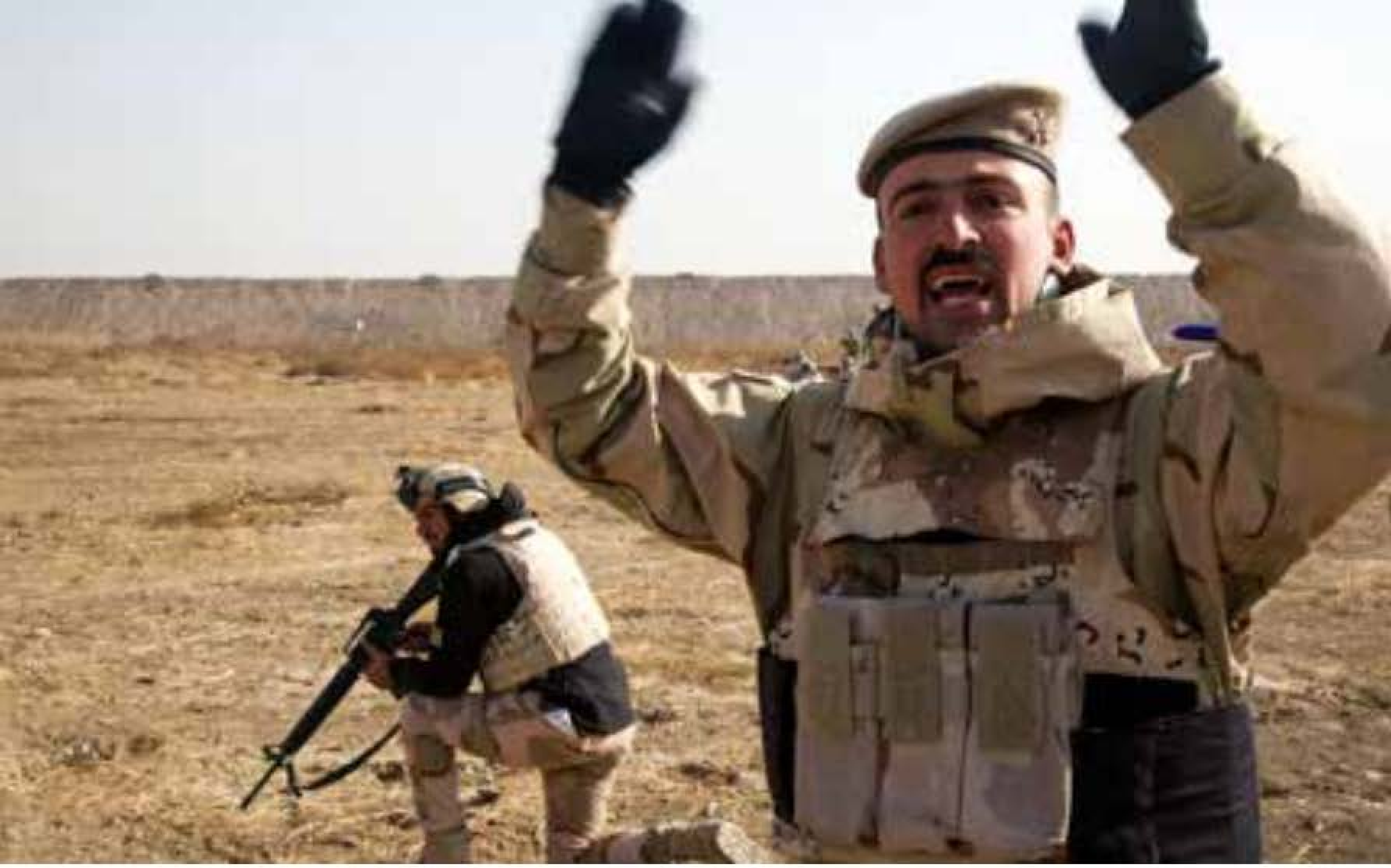
In addition to the precautions necessary for the firearm itself, ammunition must also be handled and stored with extreme care. A cartridge is a powerful explosive encased in a thin metal cylinder. Each round must be individually inspected for corrosion and defects before being loaded into a firearm and detonated. Good ammunition is clean, clearly labeled, and sealed in its original manufacturer packaging. Because oil-covered rounds can collect abrasives that may damage a rifle's interior or even cause unintentional firing outside the chamber, ammunition must not make contact with lubrication until loaded into the firearm.

Ammunition does not interact well with heat. (See Temperature, Pg. 188.) It must be properly stored in a clean and heat-stable area, away from direct sunlight. Direct sunlight almost never causes ammunition to spontaneously combust; however, extra heat can add power to the gunpowder and cause a more powerful explosion within the rifle. Also, in hot, dry environments the impacted and exploded remnants of bullets have been known to start fires, so a fire safety plan is necessary on every range.

3.f Always Remember! Firearm Safety is a Mindset

Finally, it is vital to understand that **firearm safety is more than just a set of rules**. Safety must be a set of ingrained habits that become second nature that bleed into other situations, rather than a series of conscious decisions.

For example, both the marksman and all other adults in the vicinity of the firearm are responsible for their safety. If any of the safety rules mentioned above are violated, it is everyone's duty to recognize the potential danger and respond accordingly. Children and newcomers to firearms must be consistently reminded of these safety rules and closely supervised, or



Calling for a Cease Fire

Image 14: An Iraqi soldier signals a cease fire during live fire maneuver training. Camp Taji, Iraq, 14 Dec 2016. While different organizations have different signals, **the universally understood signal for cease fire is waving your hands above your head like a madman while shouting "CEASE FIRE!"**

they must be immediately removed from the area where active marksmen are present.

Some additional safety measures to follow when not firing include separately storing firearms and ammunition and keeping them locked and secure. Firearms or ammunition must not be altered or modified without certified training. It is important not to handle firearms within 24 hours of consuming alcohol. Loaded firearms must never be carried while engaging in physical activities such as climbing fences or riding four-wheelers unless they are secured in a proper container that is customized to hold that specific firearm. It is crucial to always have complete situational awareness and not force any part of a firearm to close or open without considering the situation. Lastly, it is also essential to wear proper eye and ear protection at all times while rifles are being fired.

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Setting Up Your Equipment

By failing to prepare, you are preparing to fail.

—Benjamin Franklin, Founding Father of the United States

Before shooting starts, you must set up your equipment. While extra equipment may require extra setup, at a bare minimum, a marksman must set up their scope and properly hold their rifle. For every step onwards, you can get the fastest and best results by first consulting your records and the instructions provided by the manufacturer of your equipment.

4. Setting Up a Scope

The first and most crucial step in the setup of a long-range rifle is to ensure that the scope can perform its primary function, which is to **help you as a marksman to predict where your bullets would impact** once they have been shot. Firing a rifle without knowing where the bullets would impact is at best useless, and at worst downright dangerous!

Eventually, a precise alignment of a scope is performed with the zeroing process (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.); but that requires firing the rifle to see where bullets land on the target. And the rifle cannot be fired until the scope has at least a bit of setup performed.

Therefore before zeroing, marksman must perform a rough alignment to ensure that zeroing can occur in the first place. This alignment process entails focusing the reticle (the internal markings seen on the scope's lenses (See Image 15, Pg. 33.)), focusing the target, and repositioning the reticle to where it can predict the impact location of a bullet (i.e., the point-of-impact).

Some scopes with extra features may also require checking external settings such as battery status and light brightness. Lights are adjusted to their lowest visible setting at first because lights that are significantly brighter than the target may obscure the target.

Scopes must be set up or inspected prior to **every shooting session** because they are held to the rifle by adjustable supports, which are inherently made to adjust. All such adjustable supports (Weaver and Picatinny rail systems and scope mounts, to name a few) can misalign because they are subject to recoil after each gunshot, transported under pressure, knocked around in the field, or just plain dropped. In fact, **a loose scope can explain most of the missed shots** from experienced marksmen.

4.a Reticle (Eyepiece or Ocular) Focusing

The internal markings in a scope that form a grid system are referred to as the "reticle." The reticle can take various forms, appearing as some combination of crosshairs, dots, and dashes. (See Image 115, Pg. 133.) Reticles must be in focus to be useful. **Focusing the reticle before focusing the target is crucial**, because adjusting the reticle-focus affects both the reticle and the target, whereas adjusting the target-focus only affects the target. (See Image 15, Pg. 33.)

The reticle must be focused to the eyes of the specific marksman who plans on using the rifle, as a reticle is focused to the human eye and every person has different eyes. This is also the reason why it is required that marksmen wear any corrective glasses or contacts they plan to use while shooting. In fact, because eyesight can change over time, even the same marksman using the same rifle and scope must periodically recheck the reticle-focus of their weapon.

To focus the reticle, the marksman simply rotates the eyepiece on the scope until the reticle comes into clear focus. (Therefore this step is also known as "**eyepiece**" or "**ocular**" **focusing.**) (See Image 8, Pg. 19.) Sometimes it may be difficult to see if the reticle has any blur, so it can be helpful to aim the scope towards a bright, blank surface like the sky to create contrast.

Importantly, it is crucial for the marksman to relax their eye when focusing the reticle. This is because the eye also has the ability to refocus, and failing to relax it can lead to mistakenly rotating the eyepiece until the reticle is only in focus when the marksman's eye is unrelaxed. Not only does this cause eye strain, but it also leads to unsteady focus. To relax their eye, a marksman can take quick glances through the scope and blink while adjusting the eyepiece.

Once the optimal focus setting is found, the marksman can lock the eyepiece in place using tape or a built-in mechanism (if either is available).

4.b Target (Objective) Focusing

Once the reticle is in focus, the marksman must bring their specific target or objective into focus. This is because the scope can only bring into focus objects within a range of distance to the marksman (e.g., 100 to 200 m or yd, or 150 to 300 m or yd). This band of focus is called the "**depth-of-field**." (See Image 41, Pg. 62.) This means that the scope cannot bring into focus all of the objects in the sight picture if they are spaced longer than the scope's

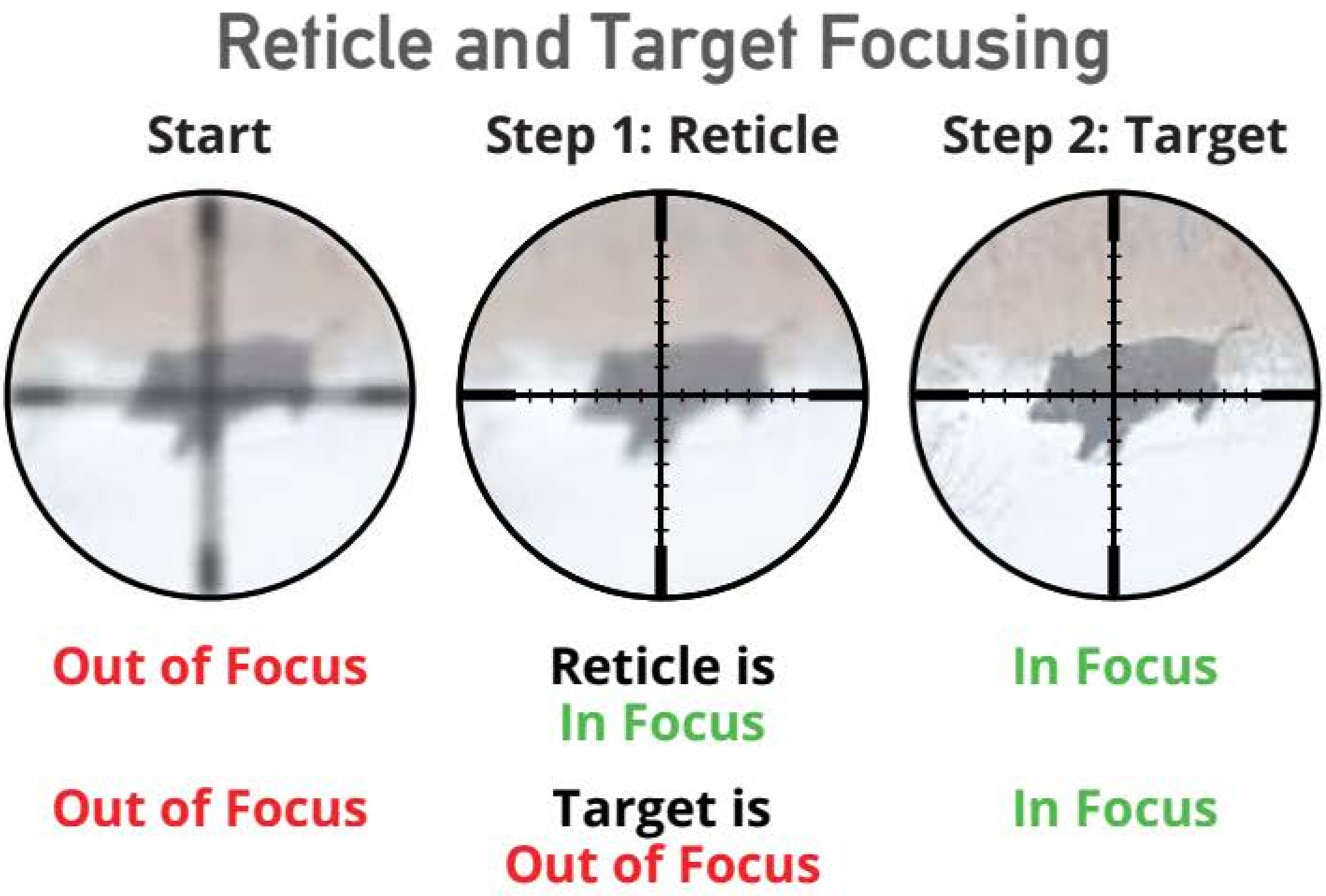


Image 15: Seeing **crisp borders and fine details** is very important for a marksman to know exactly where they are aiming and what they are aiming at.

depth-of-field. While a marksman can focus the target simply by turning the target-focus dial until their target is focused, it often helps to know the target's specific distance. (See Finding Distance to a Target, Pg. 110.) Also, whenever selecting a new target that falls outside the previous focus range, the marksman must refocus on the new target and its distance.

Notably, some scopes do not have an adjustable target focus to simplify their construction and reduce costs. That means that a target outside such a scope's depth-of-field is always out of focus; however, these scopes have a broader depth-of-field to compensate for this limitation. Non-adjustable scopes are often set with an approximately 250-m or yd depth-of-field that ranges from 50 to 300 m or yd because that is the most common range for hunters (the primary consumer group for these scopes). On the other hand, adjustable scopes may have a depth-of-field range of less than 75 m or yd.

There are two common mechanisms for adjusting the target focus. The first is the **side focus turret** (a.k.a. parallax adjustment turret). This option can be easily reached while shooting, making it more suitable for unknown-distance targets such as game. (See Image 7, Pg. 19.) The other common option is the **adjustable objective housing** (a.k.a. objective bell), which requires rotating the objective housing (i.e., the far end of the scope). Although scopes with adjustable objective housings cannot be operated while shooting, they are lighter and more affordable, making them ideal for targets that area at a known distance. (See Image 8, Pg. 19.)

Once a target is chosen, to focus on it the marksman first sets the focus to infinity and then refocuses backwards. This is done to prevent recoil from pushing forward the internal lenses within inherent looseness in the scope's internal mechanisms. It can sometimes be challenging to remember which direction to turn a side turret when under pressure. To overcome this, some marksmen use a mental trick: if the target seems too distant, the top of the turret is rolled back as if to bring the target closer. Conversely, if the target appears too close, the top of the turret is rolled away to push the target away.

In some cases, cheaper scopes may not be able to focus both the reticle and the target simultaneously due to optical limitations. In these situations, it is always a priority to focus on the reticle since marksmen need to have their attention on the reticle when firing. This is because a clearer reticle is smaller (blur increases width), and a smaller reticle is more precise.

Focus is also affected by the magnification settings. For example, the depth-of-field is inversely proportional to magnification (e.g., higher magnification causes a narrower depth-of-field). This means that when a marksman zooms in on their target with imperfect focus, the blur and parallax are exaggerated. This is typically only a problem with moving targets though, as most experienced marksmen generally can quickly find the distance to stationary targets and focus on them.

4.c Parallax (Reticle Shift)

Parallax (a.k.a. reticle shift) is a phenomenon that occurs when a target and a reticle appear to shift to the side by different increments when the marksman moves their eye. A well-adjusted scope has zero parallax, meaning the reticle appears to perfectly align with the target no matter where the marksman positions their eye in relation to the scope. (See Image 16, Pg. 35.)

Parallax is not a problem if a marksman consistently places their eye in the same location every time. However, if parallax exists and if the marksman does shift their view of the sight picture to see it from a different angle, then the reticle and target would shift differently. In other words, the reticle would become unreliable for aiming, as the point-of-aim with parallax would move all around the target, depending on the location of the marksman's eye.

This phenomenon occurs because when the marksman moves their eye, it moves the same sideways distance relative to all the objects it sees. However, objects at different distances from the marksman (such as the target and

Parallax

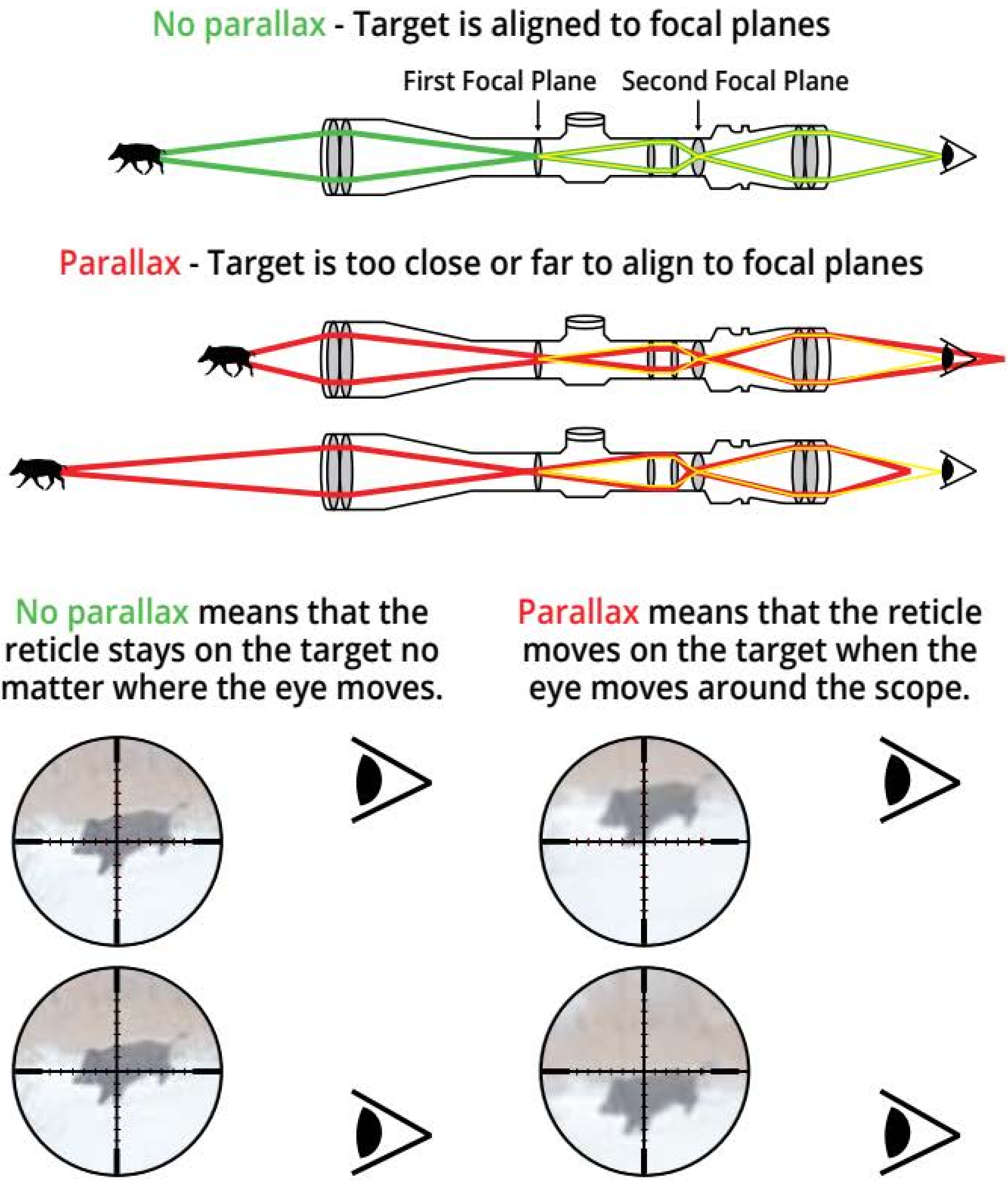

No parallax - Target is aligned to focal planes
First Focal Plane
Second Focal Plane
Parallax - Target is too close or far to align to focal planes
No parallax means that the reticle stays on the target no matter where the eye moves.
Parallax means that the reticle moves on the target when the eye moves around the scope.

Image 16: Parallax occurs when the light rays of the target do not converge on either the first or second focal planes. (Not aligning to the focal planes also makes the target appear blurry.) This is because the reticle is located on either the first or second focal plane, and so **missing the focal planes means missing the reticle**.

---

the reticle) need to move different linear distances to stay in a straight line with the marksman's eye as it moves. Therefore, without lenses in the proper locations in the scope, moving the marksman's eye makes the eye, the reticle, and the target no longer form a straight line.

In a quality scope, there is zero parallax when the target is perfectly focused. This is why the target focusing turret or dial is also known as the parallax turret or dial, it serves both functions. (See Image 7, Pg. 19.) That is also why fixed target focus scopes are also known as fixed parallax scopes, as neither can be adjusted.

That means that one way to determine if the target is optimally focused is for the marksman to move their eye around the sight picture. **If there is no parallax, then the focus is correct and vice versa**. Some marksmen believe that removing parallax is the best way to focus on the target because the human eye can accommodate an out-of-focus image by adjusting the eye's lens. In contrast, the human eye cannot fix parallax. Therefore, eliminating parallax always focuses the target with a relaxed eye lens.

With that said, cheaper scopes may be poorly calibrated, and they may not optimize focus while minimizing parallax at the same setting. This has led to much debate on which is more important: perfect parallax or perfect target focus. However, when shooting at distances where this distinction matters (e.g., more than 600 m or yd), the marksman likely has an expensive scope where target focus and parallax align, making the issue irrelevant. That being said, one trick for some cheaper scopes with this issue is to experiment with the eyepiece focus, as there may be an eyepiece setting that allows the scope to achieve an acceptable balance between reticle clarity, target clarity, and minimum parallax simultaneously.

Fixed parallax scopes, with no adjustable parallax, cannot achieve zero parallax except exactly at their set distance. However, they can still be a good option because parallax error is minimal within a significant range For example, a 100-m (109-yd) fixed-parallax scope may have a maximum difference of 10 cm (3.9 in) between the zero-parallax point-of-aim and the shifted parallax point-of-aim at 400 m (438 yd) and 50 m (55 yd), regardless of where the marksman looks through the scope. (The lower limit would be closer to 100 m (109 yd) because parallax increases exponentially as the distance becomes shorter.) Moreover, the 10 cm (3.9 in) difference is rarely noticeable because parallax error is reduced with a consistent and centered eye placement. Big-game hunters particularly benefit from the simplicity of fixed-parallax scopes because they typically engage large targets at distances within 400 m or yd.

4.d Adjusting Elevation and Windage Settings with Turrets

A scope's reticle can be adjusted within the scope without moving the rest of the scope. This adjustment is made using the two dials or turrets that are present on virtually all scopes: the elevation turret on the top of the scope

Adjusting Scope Turrets

Image 17: A competitor in the USASOC International Sniper Competition adjusts his elevation turret (the top one). Fort Bragg, NC, 22 Mar 2021. He uses his trigger hand (See Image 22, Pg. 42.) so that his support hand can stay in place, allowing the sight picture to remain unchanged. (The right-side turret is the windage turret.)

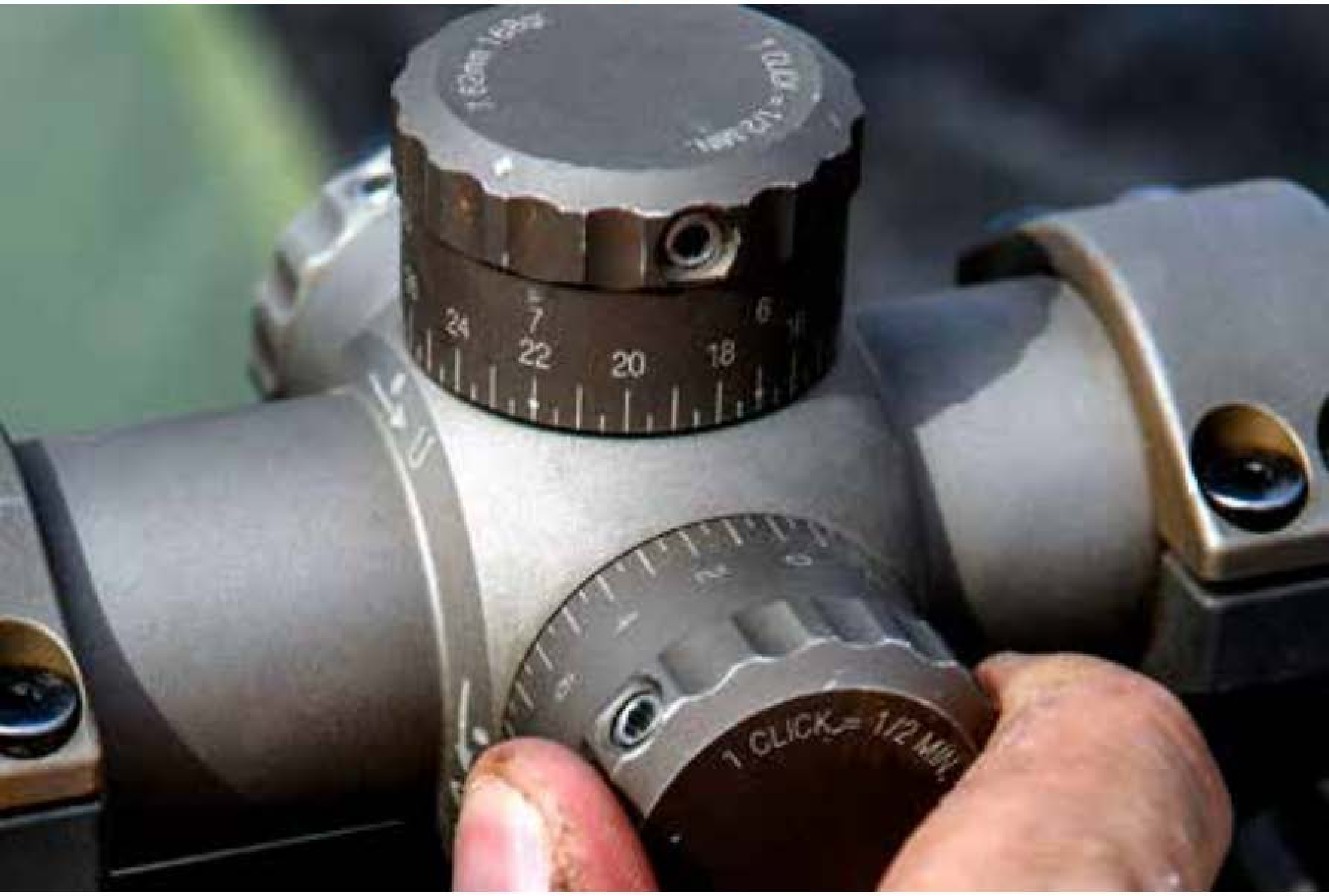


Image 18: This scope has markings to help operate it. On the top of each dial is written "1 Click = 1/2 Min." ("Min" is "minutes-of-angle"). This means that whenever a turret is rotated, every 2 **audible clicks** indicates the reticle has moved by 1 minute-of-angle. The numbers show how many minutes past 0 the turrets have been rotated. The hex screws indicate that this rifle has removable turret caps, so when the turret is at 0 the rifle is at its zero point. (See Zeroing, Pg. 79.)

and the windage dial on the right side of the scope. (See Image 8, Pg. 19.) Rotating the elevation turret moves the reticle vertically within the scope, and rotating the windage turret moves the reticle horizontally. (See Image 17, Pg. 37.) (Many scopes also have a third turret on the left that adjusts target focus and parallax.) (See Target (Objective) Focusing, Pg. 32.)

Because the two dials are mechanically identical, left-handed marksmen sometimes rotate a scope without a parallax turret 90° so that the windage turret is on top and serves as the elevation turret, and the elevation turret is on the left side and serves as the windage turret. This can be a difficult arrangement for complicated reticles, however, because the reticle would also be rotated 90° with the scope.

Turrets on scopes are marked in either minutes-of-angle (MOA) or milliradians (mils). (See Angular Distance, Pg. 237.) When a marksman rotates the turret, they both feel and hear **distinct clicks** indicating the movement of the internal parts that adjust the reticle. (See Image 18, Pg. 37.) Each click represents a specific measurement, which can vary between manufacturers and is always specified in the scope's manual.

For example, a single click on a scope may correspond to a 0.25-mil adjustment, while on another scope, it may signify a 0.1-mil adjustment. Because the click values differ between scopes, communication about adjustments always uses the actual MOA or mil measurement, not the number of clicks. Additionally, some cheaper scopes may not be "**repeatable**," meaning that a click in one direction does not have the same measurement as a click in the opposite direction.

Similarly, the number of rotations a turret can make also varies from scope to scope. Some turrets only rotate for one 360° revolution, while others can complete multiple revolutions. Due to the variety of systems, a marksman must always review and examine the instructions for their specific scope.

4.e Getting to Mechanical Center

The phrase "adjusting a reticle" means to move it within the scope. If the reticle is adjusted so far that it hits the interior of the scope, it can no longer be adjusted in that specific direction. Therefore, to ensure that a scope can always be adjusted up, down, left, and right, the marksman must ensure that the reticle is roughly centered within the scope, and that it also points approximately towards the target.

When turrets are positioned in the middle of their adjustment range, that is called the "**mechanical center**" because it is in the physical center of the

Optically Centering a Reticle

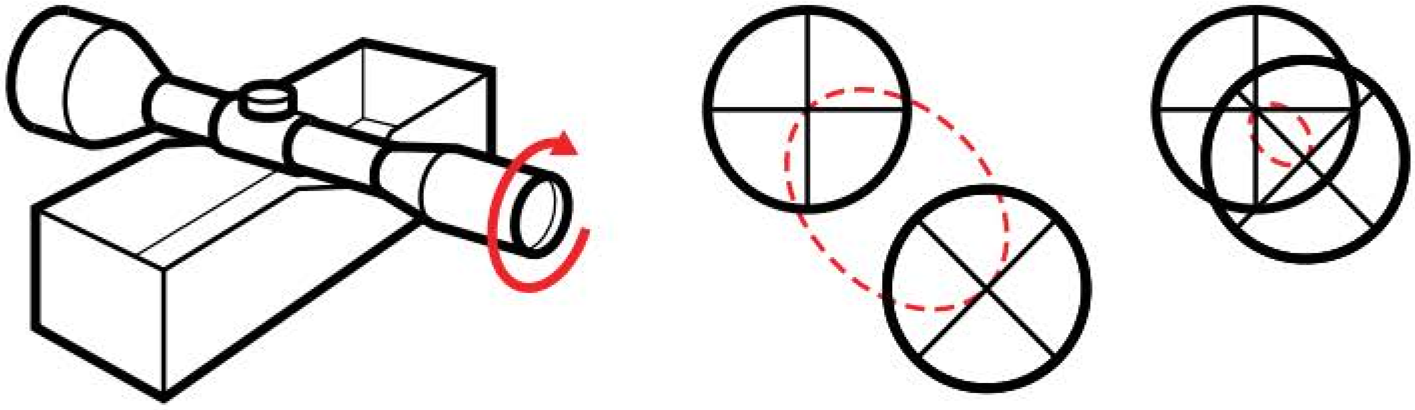


Image 19: Placing a scope in a rest and spinning it rotates the reticle. If the reticle's center rotates, then the reticle is not at the scope's optical center, which is a good approximation of the mechanical center. Therefore to get to the optical center, a marksman can adjust the turrets until **the center rotates on a point**.

scope. This contrasts with the "**optical center**," which is when the reticle is in the center of the scope's sight picture. The two are always close, but may or may not always be the same.

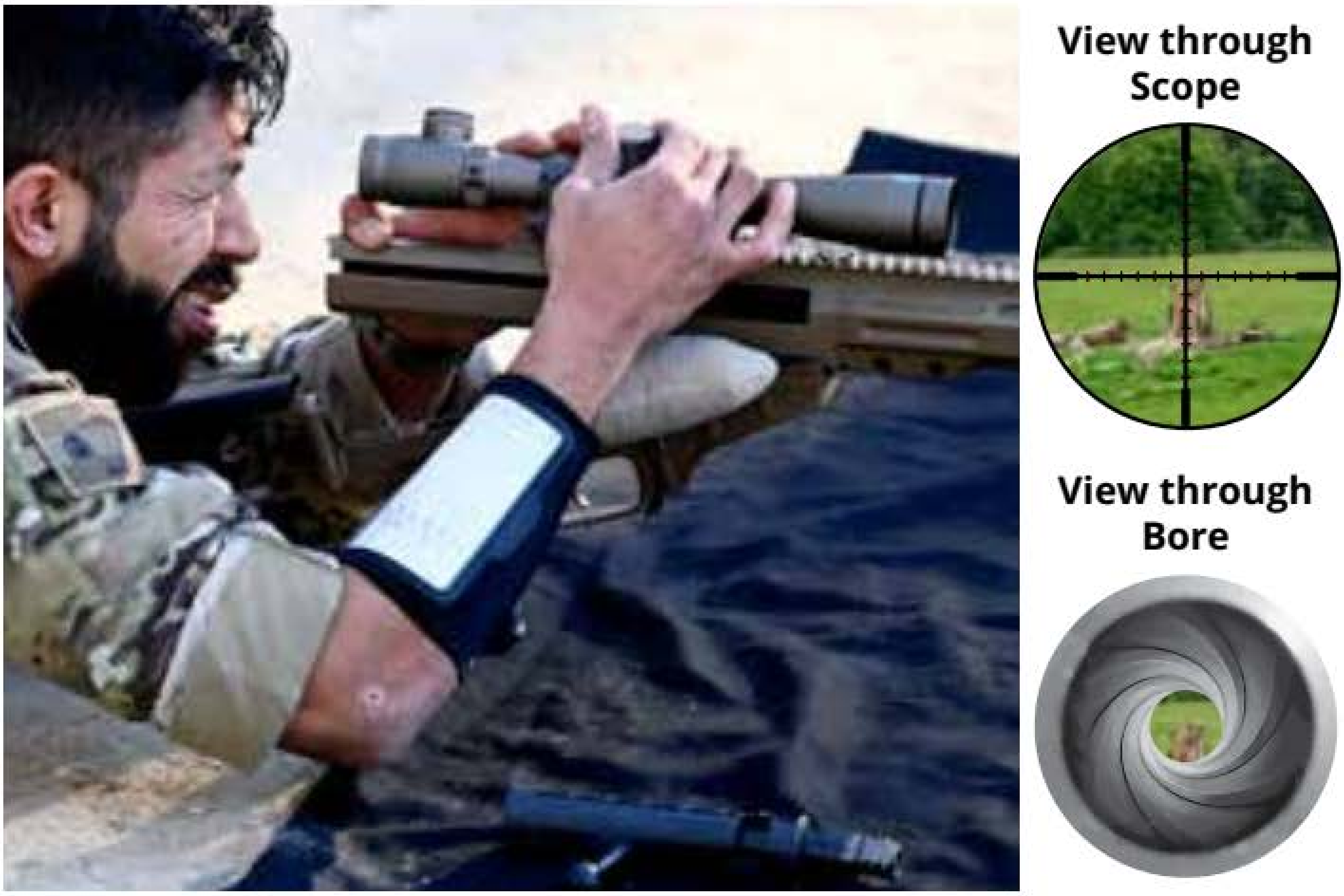
To mechanically center the reticle and still point it at a target, a marksman may need to adjust their scope mounting. Therefore, mechanical centering is done before mounting a scope, and may require removing and remounting an existing scope back onto its rifle.

To find the mechanical center, the marksman adjusts both the windage and elevation turrets all the way in one direction. Then, they rotate the turret completely in the opposite direction and count the number of clicks it takes for a full rotation. (This step can be skipped if the scope's click range is listed in the manual.) Next, the marksman rotates each turret in the opposite direction, but only half the number of clicks it took for the full rotation. This brings the turret to its mechanical center.

Another, faster way to find an approximate mechanical zero is to rotate the scope when it is detached from the rifle. When the reticle is not at the optical center, its center rotates in an elliptical pattern. However, when positioned at the optical center, the reticle's center rotates on a point. (See Image 19, Pg. 39.) Therefore, the scope can be set to an approximate mechanical zero by adjusting the turrets until the center of the reticle rotates on a point.

If the scope cannot be removed from its rifle, the marksman can place a small mirror directly on the end of the scope and look through the scope. Thereafter, the marksmen can see both the reticle as well as its reflection. To optically center the reticle, the marksman adjusts the turrets until both the reticle's center and its reflection's center align (converge) onto the same point.

Bore-Sighting a Bolt-Action



View through Scope

View through Bore

Image 20 et al: A competitor in the USASOC International Sniper Competition bore-sights a rifle by **removing the bolt** and looking down the bore. Fort Bragg, NC, 21 Mar 2023. Something like a stump can be an excellent reference point. Note that everything in the right images is centered.

4.f Bore-Sighting

When installing a scope for the first time or if the scope is significantly misaligned, it is necessary to perform a process called "bore-sighting." Bore-sighting involves aligning the rifle's boreline (i.e., the path a bullet follows as it exits the barrel) with the sightline (i.e., the sightline as the marksman looks through the scope). This initial alignment can aid in the accuracy of subsequent adjustments. (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.)

There are two commonly used methods for bore-sighting a rifle. The first method involves **removing the bolt of a bolt-action rifle** to have a clear view down the bore. (See Image 20 et al, Pg. 40.) The marksman then aims the rifle at a distinct target such as a paper target, vehicle headlights, or white transformer boxes.

The marksman looks down the rear of the bore to see the target, making sure that the muzzle opening is centered in the bore and the target is centered in the muzzle opening. (A "muzzle" is the end of a barrel.) Once the bore is aligned with the target, the marksman looks through the scope's sight picture and adjusts the reticle to align with the target. When making these

Bore-Sighting a Semi-Automatic

Image 21: A Gunner's Mate 3rd Class, assigned to Naval Mobile Construction Battalion 74, Headquarters Company, bore-sights an advanced combat optical gunsight (ACOG) **using a laser bore light**. Camp Mitchell, Rota, Spain, 20 Dec 2010. Different laser bore-sighters and sights work slightly differently, so it is vital to read the instruction manual for the specific equipment being used prior to using it.

adjustments, it is easy to accidentally bump the rifle. Therefore, the process of physically centering the bore on the target and aligning the scope must be repeated and verified at least a few times to achieve the best results.

The second method of bore-sighting is used for semi-automatic rifles, since their construction prevents a marksman from seeing down the bore from the rear. This method involves using a specialty tool. One such tool is the **bore-sight laser**, which can be placed in the rifle's muzzle. It emits a red dot that the marksman can then align the scope with. The advantage of this method is that even if the bore moves, the dot of the laser moves with it, allowing the rifle to be moved during the bore-sighting process. Another tool is a **bore-sighting collimator**, which is also inserted into the rifle's muzzle. The collimator is aligned to the muzzle, so aligning the scope to the collimator also aligns the scope to the muzzle.

While the reticle can be adjusted via the scope's turrets during the bore-sighting process, the process itself can move the reticle off its mechanical center. Therefore, a better alternative to adjusting the turrets is to adjust the scope's mounts so that the turrets retain their full ranges of motion.

Once the marksman is confident that a bullet shot through the bore would land close enough to their point-of-aim, they can proceed to the next step in calibrating a scope to give precise readings, that is "zeroing." (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.)

Holding an Unsupported Rifle

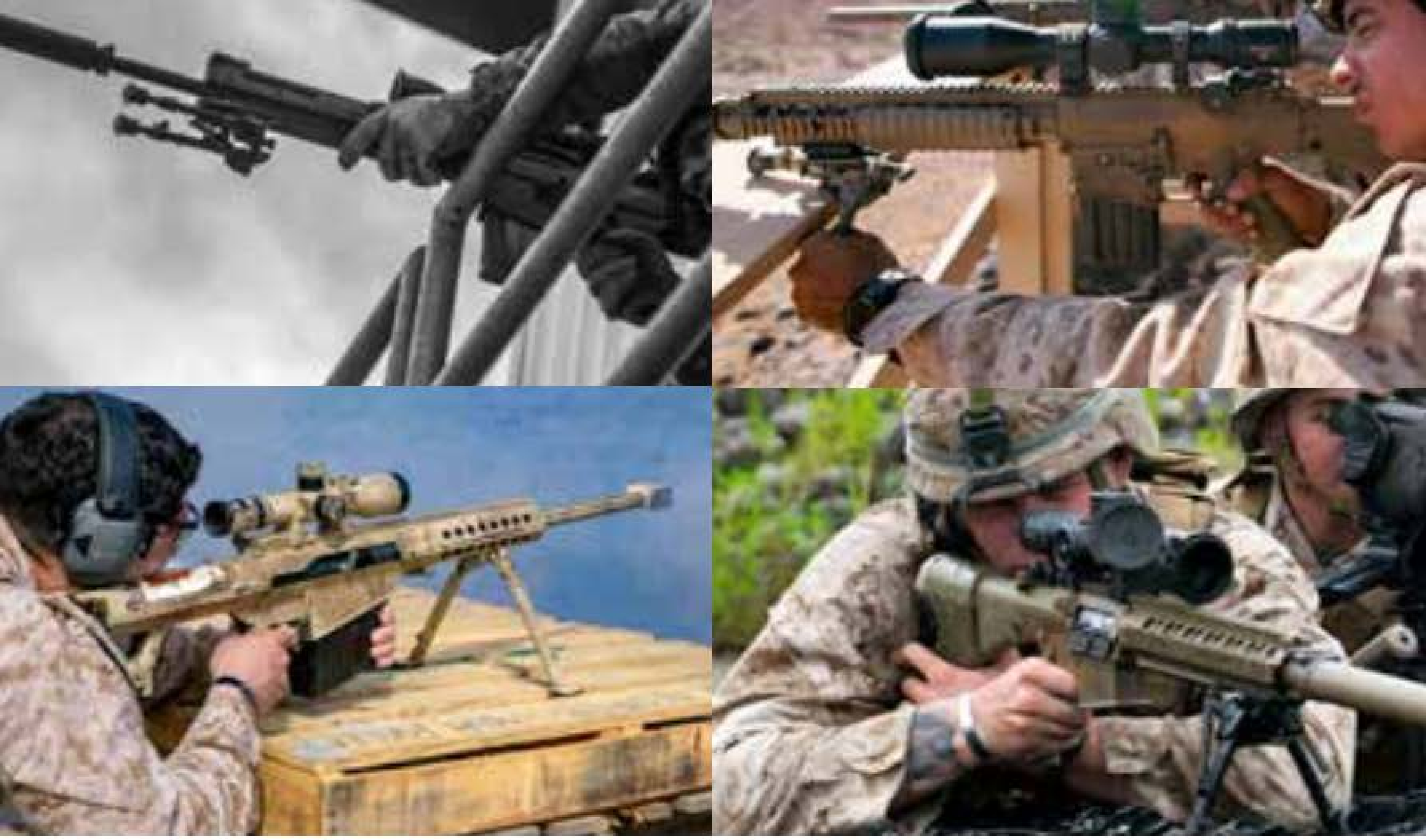
Image 22: A Clarksville, Tennessee resident and veteran fires his rifle during the 2018 Fort Benning Multi-Gun Challenge from an **unsupported position**. Fort Benning, GA, 17 Nov 2018.

5. Holding a Rifle

Rifles are designed and built to be as intuitive as possible, so this section may be common sense to some people. However, it is never a mistake to cover the basics. A marksman contacts a rifle in five distinct places: the two hands, the shoulder, the cheek, and the trigger finger. Each location has a best practice for interfacing with and supporting a rifle without interfering with the process of aiming and firing the weapon.

The one rule that is constant throughout this section is that **consistency is the key to accuracy**. To be consistent, first everything must be rigidly held; many marksmen attempt to maintain rigidity through muscle control, but that can certainly lead to fatigue and shaking, resulting in increased inaccuracy over time. This is inevitable. No human being can hold a heavy piece of metal and wood (or polymer) for an extended period of time without experiencing muscle pain and fatigue. Therefore whenever possible, it is important to hold a rifle in a way that minimizes the involvement of muscle tissue, instead **resting the weight on tendons and bones**.

Marksmen must then hold the rifle in this same relaxed position that relies on bones and tendons every time they shoot, allowing it to become automatic. A useful way to test the effectiveness of their habits is for the marksman to close their eyes and attempt to get into the same shooting position multiple



Holding a Supported Rifle

Image 23 et al: These marksmen are firing from a **supported position** because the rifles are supported by (clockwise from top left) a pipe, a piece of wood, a bipod, and another bipod. The support hand is in a different location in every image (at the marksman's discretion) because each object replaces the support hand's support.

times. If the same sight picture is consistently achieved, then their habits are effective. (See Natural Point-of-Aim (NPA), Pg. 89.)

5.a Support Hand

The support hand is by definition the hand that does not pull the trigger. (That hand is the "trigger hand" or "firing hand.") Its job is to support and stabilize the front of the rifle. The support hand is most important when the marksman is firing from an "unsupported position," which means there is no support other than the firing hand (e.g., no bench or tripod).

In an unsupported shooting position, the support hand must be placed as far forward on the stock as possible to provide finer control over the rifle. (See Image 22, Pg. 42.) The support hand holds the rifle in the crook of the thumb with the palm facing upwards to prevent the palm from pushing the rifle sideways. The entire palm firmly grips the rifle with the thumb pointing forward in order to help maintain control during recoil, but not so firmly that the hand and rifle start shaking.

The marksman's hand must never touch the barrel during live-firing unless there is a barrel shroud or handguard covering the barrel because barrels get hot enough to burn skin and gloves. The ejection port and action must remain uncovered and clear of any obstructions, as this could hinder both bullet and casing ejection.

When shooting from a supported position, since the rifle is already stable, the support hand may be moved towards the middle of the rifle for easier maneuvering and pivoting, or wherever else the support hand can help maintain the stability of the rifle. (See Image 23 et al, Pg. 43.)

Specifically when using a bipod or other stabilizing forward support, the support hand can be positioned at the rear of the rifle to provide support to the buttstock from below. This positioning creates a stable tripod with two legs at the front and the support hand at the back. The marksman can form their hand into a fist and rest the buttstock (i.e., the rear part of the stock) on it, or hold a sandsock (i.e., a bag filled with fine material like sand or rice) under the buttstock. Making a fist or using a sandsock allows for slight alterations to the sight picture. Squeezing the fist or sandsock makes it taller and moves the sight picture down, while relaxing the squeeze raises the sight picture. (See Precisely Adjusting the Sight Picture, Pg. 139.)

5.b Shoulder Pocket

A support hand or forward support (e.g., a bipod) stops the rifle from moving forward as the torso presses into the rear of the stock (i.e., the "buttstock"). The location on the torso that the rifle presses into is called the "shoulder pocket," which is where **the pectoral muscle ends and the shoulder begins**. (See Image 24, Pg. 45.) Buttstocks and recoil pads (i.e., rubber or plastic pads fixed to the end of stocks) are vertical and thin to allow them to fit into an average person's shoulder pocket.

The shoulder pocket is the lowest point in the local area, so it is the most secure location to hold the rifle during a shooting session. When properly positioned, a rifle can be held with only the support hand holding the front of the rifle and lightly pressing the buttstock into the shoulder pocket.

Some marksmen opt to deepen the shoulder pocket by holding their firing-side elbow away from the body, which exaggerates the front deltoid muscle; however, hunters and military marksmen must be cautious of this technique (called "chicken winging") as it may cause their elbow to catch on something if they are moving.

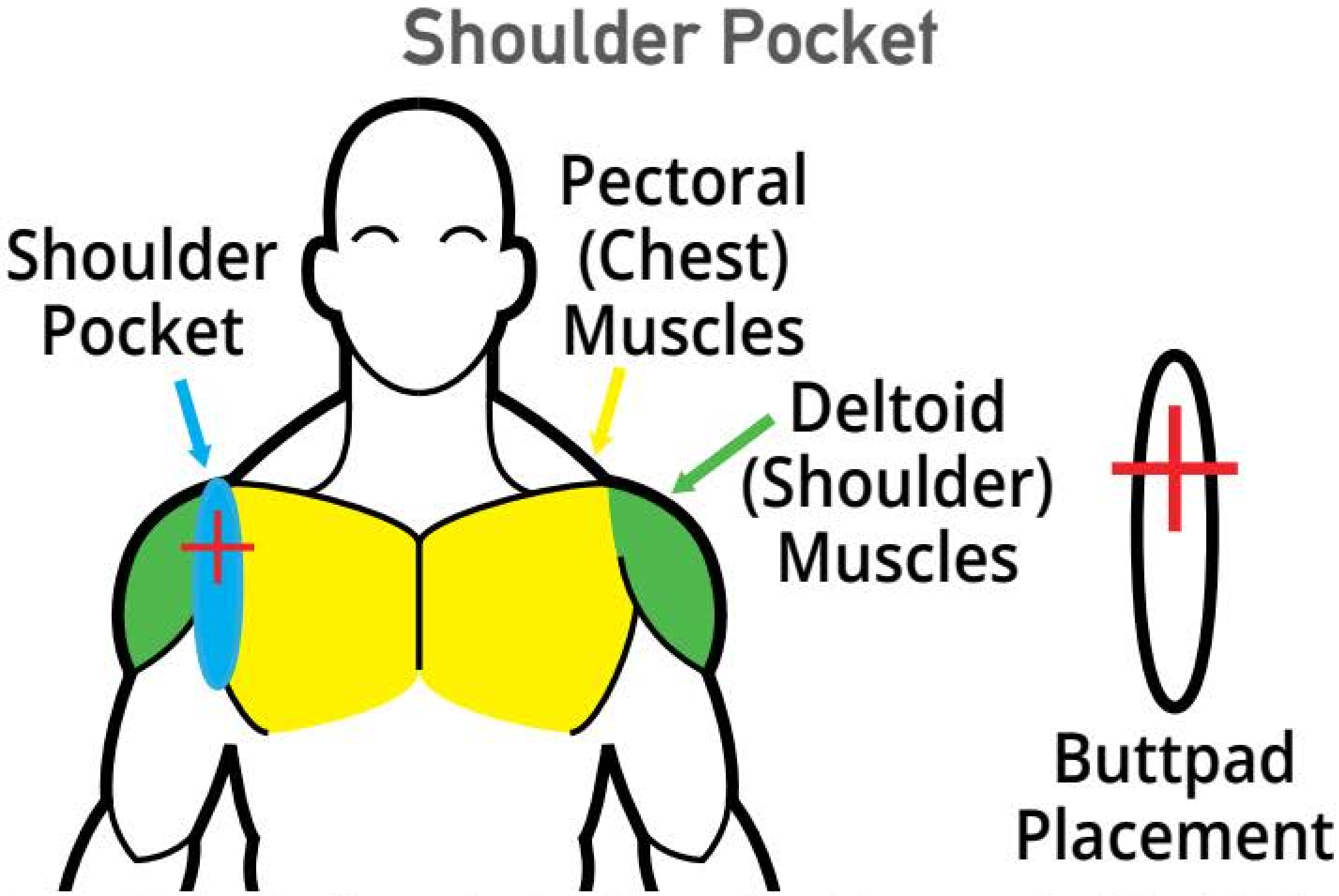


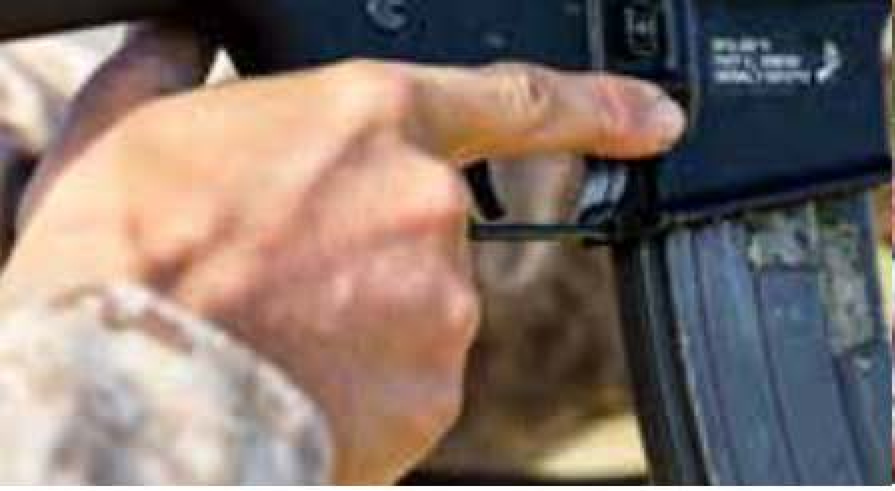
Image 24: The shoulder pocket is at the meeting of the pectoral and the deltoid.

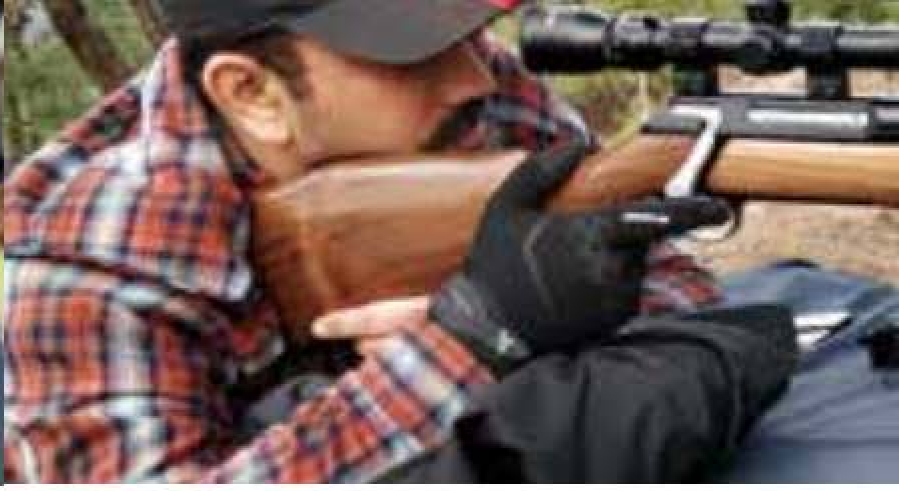
Once the rifle is in the shoulder pocket, marksmen lean into the rifle during the firing sequence to absorb the recoil into the shoulder. Maintaining consistent pressure is crucial, as sudden tensing into the stock in anticipation of recoil is a primary cause of inaccurate shooting.

Thick gear, clothing, or suspenders **may obstruct the shoulder pocket**, leaving no space for the buttstock. Shooting in this manner is uncomfortable at best and unsafe at worst, since the rifle could have uncontrolled movement during recoil. The rifle would also appear to be too long, since length-of-pull measurements are for unobstructed shoulder pockets. (See Image 5, Pg. 17.) Therefore, it is essential to move any gear out of the way to find a secure pocket hold for the most precise shooting positions.

However, sometimes a rifle is supported by equipment such as a tripod or vice so that human support is superfluous. If the rifle is stable enough to stand on its own, **the shoulder pocket becomes unnecessary**, and the marksman can simply rest the buttstock anywhere on their chest. (See Image 87, Pg. 107.)

And when shooting from the prone position (i.e., on one's stomach), there is no true shoulder pocket since the chest is facing the ground. (See Image 64, Pg. 98.) However, while in the prone position it is still a good idea to first place the rifle in the approximate pocket and then lean forward to create a repeatable shooting position and maintain pressure on the buttstock.





Trigger-Hand Grip on a Rifle

Image 25: This marksman is using a rifle with a **military-style grip**. He is holding the grip with his palm, placing his trigger finger outside the trigger well, and operating the safety mechanism with his thumb.

Image 26: This marksman is using a **hunting-style rifle with no grip**. So his thumb goes on top or over the rifle. His trigger finger is in the trigger well because he is ready to fire. J&K, India, 21 Feb 2019.

5.c Trigger Hand (Firing Hand)

Contrary to the support hand, the trigger hand's main role is to pull the trigger. The first step in achieving a good trigger pull is establishing a **firm grip** to ensure consistency and repeatability, and to prevent the trigger finger from shifting due to recoil.

In technical terms, a "firm" grip refers to the strongest hold that does not cause any trembling that affects the scope's point-of-aim. (Therefore, a firm grip is not actually powerful.) Trembling is caused by muscle fatigue, which occurs when stressed muscle fibers are replaced by fresh muscle fibers. Novice marksmen often grip their rifles too tightly, which becomes noticeable when their fingernails turn white due to excessive pressure before firing. (Performing hand exercises can significantly improve baseline hand strength and thereby a rifle grip.)

To properly grip a rifle, the trigger hand's palm firmly presses against the stock while the crook of the thumb rests either in the pistol grip for military-style rifles (See Image 25, Pg. 46.) or on the top of the stock for hunting-style rifles (See Image 26, Pg. 46.). This is because touching the palm to the stock can minimize the impact of the trigger pull on the trigger hand's grip. Then the fingers securely wrap around the stock and grip the rifle. For better grip, some rifles may have features such as palm swells or finger grooves.

However, the trigger (a.k.a., index) finger alone remains outside the trigger well (i.e., the space between the trigger and the trigger guard). It is crucial to **refrain from placing the trigger finger on the trigger** unless there is an intention to fire the rifle.

Trigger Finger Pull

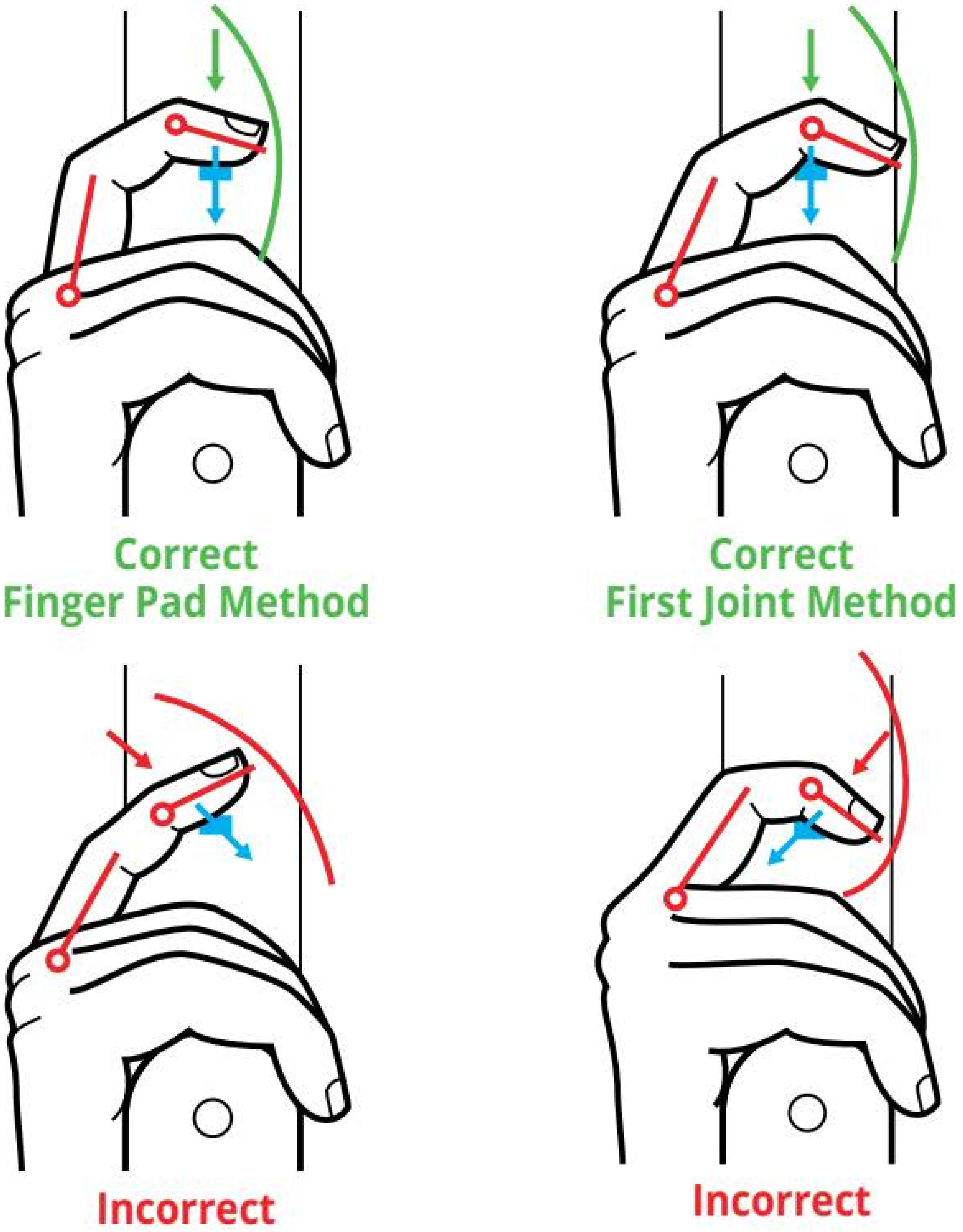


Image 27: Fingers rotate about their knuckles, as seen in the top left diagram. This rotation is difficult to transform into linear force. The arrows indicate the **direction of the force** applied by the finger.

When the trigger is pulled backward, the hand shape changes, making it difficult to maintain a consistent grip. This is why it is essential to press the buttstock firmly into the shoulder pocket. By doing so, for the trigger hand to twist the rifle, it would have to overcome the force of the entire torso pushing into the back of the rifle. To the same effect, many marksmen choose "lighter" (i.e., requiring less force to depress) triggers, reducing the force that the trigger finger can apply to the rifle. In fact, when using a low-power rifle in a supported position, the trigger hand may not need to support the rifle at all, allowing it to avoid gripping the stock or affecting the rest of the rifle.

Besides its primary role of pulling the trigger, the trigger hand is also responsible for operating the safety mechanism on most rifles. And when the support arm cannot provide complete stability, or in instances where the rifle is too powerful, the trigger hand can also help stabilize a rifle; although this may negatively impact accuracy.

5.d Trigger Finger

Proper placement of the trigger finger is crucial to maintaining rifle alignment during the trigger pull. Usually, the trigger finger makes contact with the trigger in the middle of the farthest pad of the finger. (See Image 27, Pg. 47.) This position allows marksmen to efficiently translate their fingers' rotational movement into the trigger's backward linear movement. Importantly, there is no other contact between the trigger finger and the gun to prevent any part of the finger from dragging on the firearm.

However, as long as the trigger is pulled straight backward without any horizontal or vertical movement, any finger position in relation to the trigger is acceptable. Hand placement may vary among individuals due to differences in hand size and shape. Therefore, the natural placement of the finger on the trigger, whether it is in the middle of the finger pad, at the first knuckle, or wrapped around the trigger, **can all be equally effective with practice and muscle memory**. It is never advisable to force the trigger finger into a specific position that compromises a comfortable grip.

Some instructors suggest placing the trigger finger first and then gripping the firearm. This approach allows for the intentional positioning of the trigger finger. However again, intentional positioning assumes that one position is ideal for shooting the weapon which is untrue. It also raises safety concerns as it advises placing a finger on the trigger without the intention to fire, which is a direct violation of basic rules of firearm safety.

One trick for a direct backward pull, is to make the proximal phalanx of the finger (i.e., the bone between the second and third knuckle) remain parallel to the barrel and aligned with the firing arm, without angling up or down. (See Image 25, Pg. 46.) (Adjusting the finger slightly up or down on the trigger can help maximize mechanical advantage, considering that the trigger acts as a lever; however, the entire hand may have to move to accommodate this.) To stop the trigger hand from shifting, some experts recommend focusing on keeping the proximal phalanx and wrist pointing straight at the target while depressing the trigger.

Eye Positioning

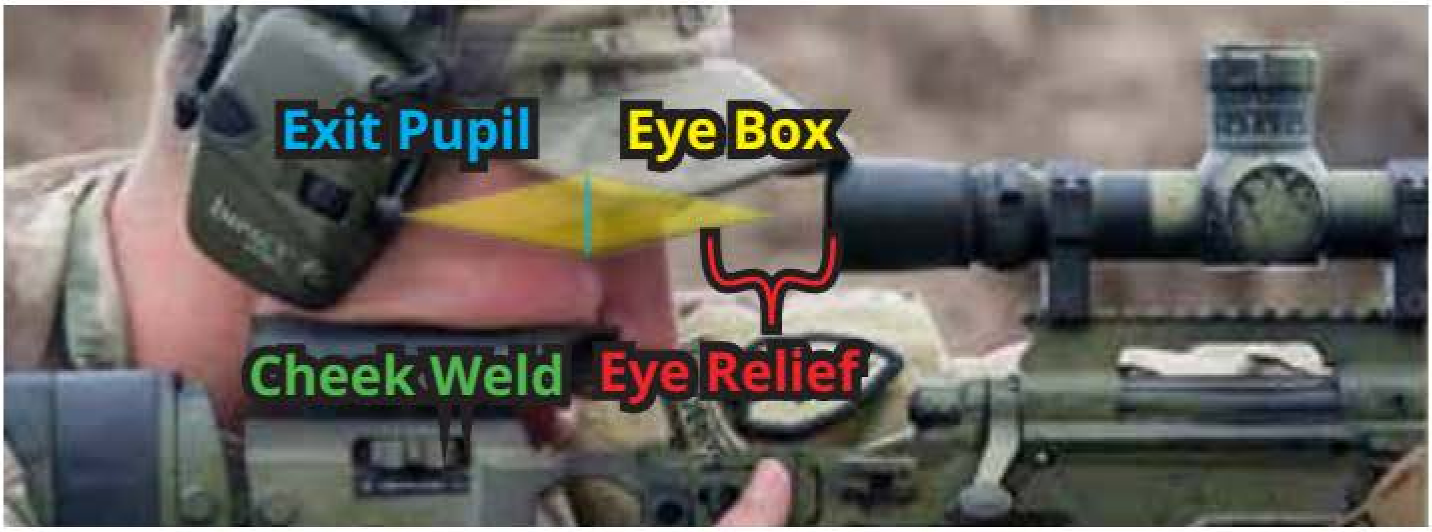


Image 28: A good **cheek weld** places the marksman's eye in the eye box. The **eye box** is a three-dimensional shape (i.e., a double cone) made by the scope in which a marksman can place their eye and see the sight picture at full brightness. The maximum diameter of the eye box is called the "**exit pupil**," and it is as large as the scope's front lens diameter divided by the magnification setting (e.g., a 40mm lens at 4X magnification has a 10mm exit pupil). "**Eye relief**" is the distance from the back of the scope to the useful section of the eye box.

Scope Shadow

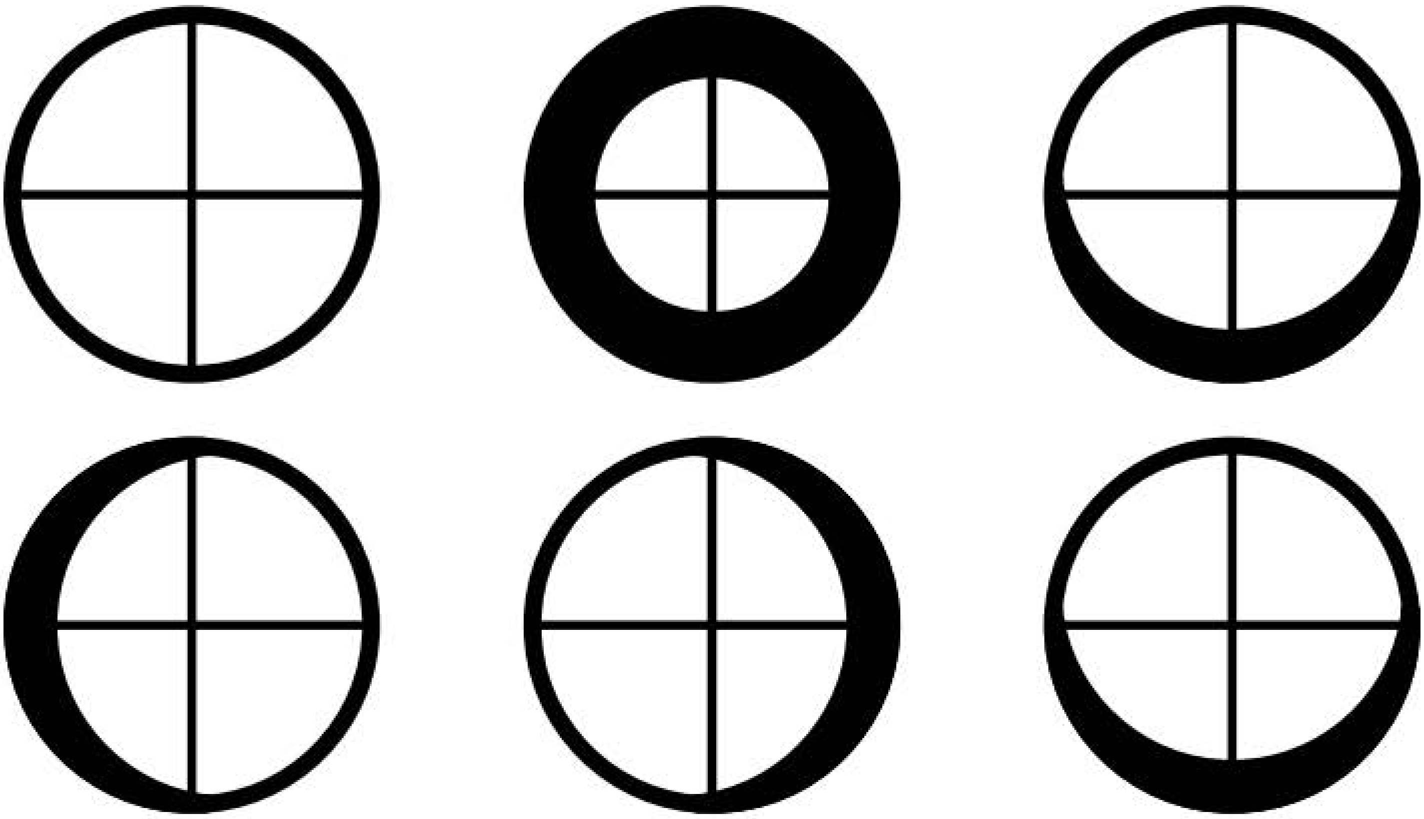


Image 29: Scope shadow is a **thick black border** seen through the scope. When looking through a scope, the only correct sight picture is one with no scope shadow (top left). When scope shadow is present (See Image 101, Pg. 116.) (See Image 102, Pg. 116.), it indicates that the marksman has poor eye relief because they do not have their eye positioned correctly on the stock. This in turn, can be due to a poor check weld or a rifle that does not fit the marksman (e.g., bad length-of-pull (See Image 5, Pg. 17.)).

5.e Cheek Weld and Eye Relief

"Cheek weld" refers to how the marksman's cheekrests on the rifle's stock. The term "weld" can be misleading because it implies forceful pressure. However, in reality, the marksman simply rests their head softly on the stock. Achieving a proper cheek weld is usually straightforward: the marksman turns their head slightly sideways and **rests their cheek on the stock**. Ideally, the head remains mostly vertical. Excessive sideways bending can strain the neck, compromise balance, and affect the marksman's perception of rifle cant. (See Eliminating Rifle Cant, Pg. 144.) When shooting in a supported or prone position, the entire body is adjusted downward to maintain a proper cheek weld, rather than solely relying on neck adjustment.

The purpose of a cheek weld is to position the marksman's dominant eye to view the sight picture through the scope. The sight picture is only visible from specific positions behind the scope. The range of these positions where the eye can see the full sight picture is called the "**eye box**." (See Image 28, Pg. 49.) The eye box becomes smaller as magnification increases; therefore, marksmen need to practice their cheek weld at every magnification setting they plan to use. Larger objective (i.e., front) lenses create larger eye boxes, which is why they are necessary for high-magnification scopes.

The distance known as "**eye relief**" is between the usable section of the eye box (i.e., wider in diameter than the marksman's pupil) and the scope's eyepiece lens, and is typically 5 to 8 cm (2 to 3 in). This is easily measured because before the limit of eye relief, the marksman has an unobstructed field-of-view without the presence of "**scope shadow**." Scope shadow is a circular or crescent-shaped shadow in the sight picture which reduces the sight picture's size. (See Image 29, Pg. 49.) (See Image 101, Pg. 116.) When these shadows are present, a fired bullet would likely not land where the marksman intended due to parallax. (See Image 16, Pg. 35.)

Having a consistent and stable cheek weld is crucial for maintaining a consistent and stable sight picture. If a marksman removes their cheek from the stock while firing, the release of pressure can affect the alignment of the rifle. To check for consistency in their cheek welds, marksmen can close their eyes while obtaining a cheek weld. If the sight picture is thereafter fully visible, they have a good cheek weld. But if any scope shadow is present, marksman must continue to practice creating a consistent cheek weld. To help with consistency, marksmen can **affix a textured material** to the stock to feel the correct cheek position without looking at the stock.

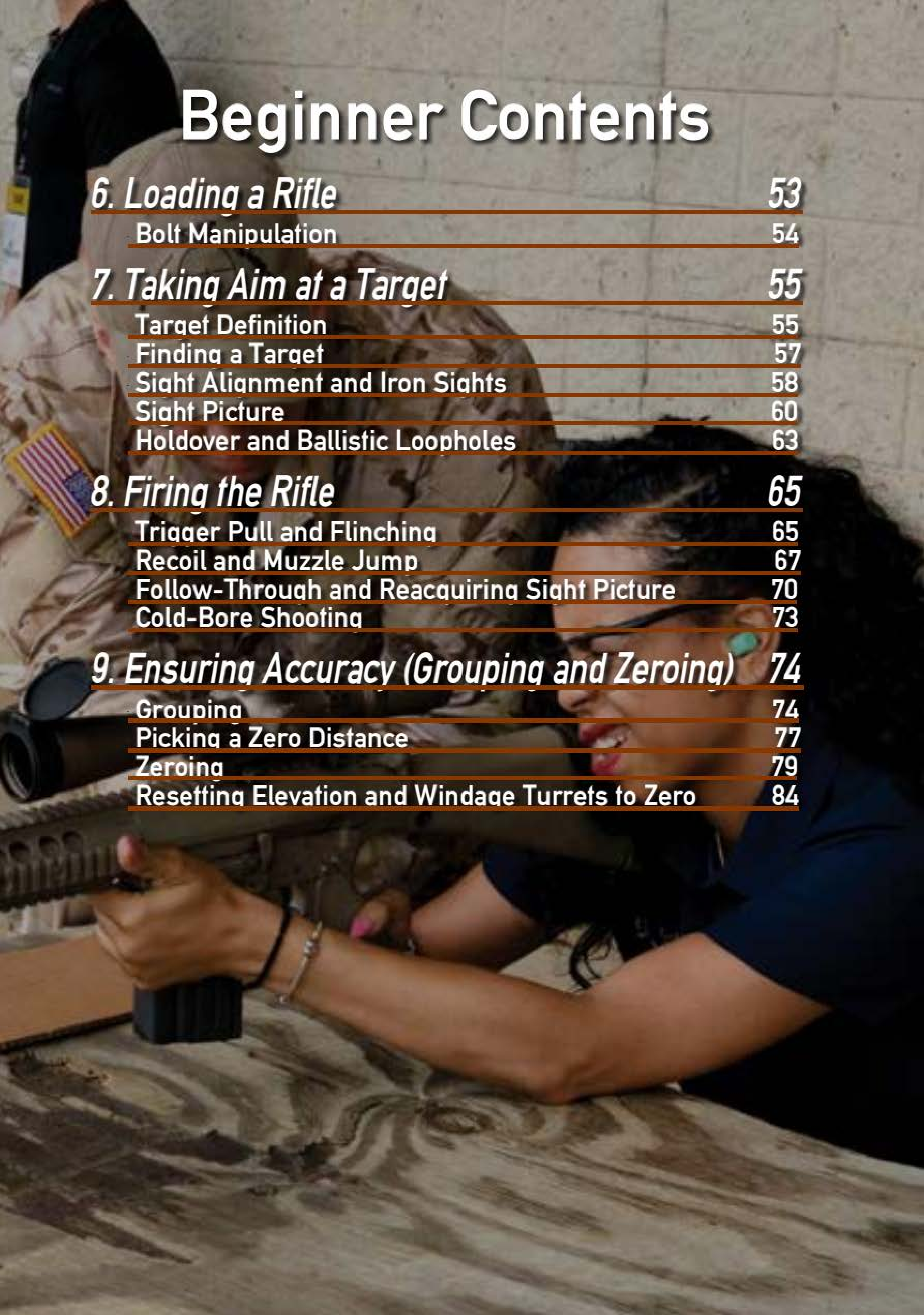
Image 30: **Benchrest shooting** uses a bench, but also holds a rifle stable using equipment such as rifle stands and vices.

The appearance of a stable cheek weld depends on the shape of the rifle and the marksman. If the scope is mounted high and the sight picture is too high, the marksman can attach a cheek piece to the rifle's stock to elevate the cheek weld area (a.k.a., the stock's "comb"). Marksmen who would benefit from a cheek piece are easily identified because they frequently move their heads up and down in search of a comfortable eye position. Marksmen who would benefit from remounting the scope forward or backward are also easily identified because they also move their head to achieve a good sight picture.

5.f Benchrest Shooting

Unlike other shooting styles where the hands or shoulder support the rifle, benchrest marksmen utilize a stable platform, often a bench (hence the name). Typically, both the front and rear of the rifle rest on supports, such as a bipod or sandbag at the front, and an adjustable rest at the rear. This setup provides an incredibly stable shooting platform that still allows the marksman to make adjustments by subtly squeezing or adjusting the support, usually the rear support, rather than the rifle itself.

In benchrest shooting, minimizing physical contact with the rifle helps to substantially reduce human error (making much of this section moot for the discipline). For example, custom triggers with very light pull weights (e.g., 2 oz or 0.5 N of force to depress the trigger) are commonly used to more precisely control the trigger. Furthermore, recoil management is minimal to avoid affecting the rifle during the firing sequence. In fact, some marksmen employ the "free-recoil" technique, only gently depressing the trigger while allowing the rifle to recoil without human restraint.



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Beginners
(0 to 100 Meters or Yards)

Being an expert is getting the basics right every time.

—Common saying among U.S. Special Forces

Once setup is complete, a marksman can begin the process of loading and firing ammunition. This process starts, as all do, with the basics. For long-range shooting, that means properly using your sense of sight and being consistent from shot to shot. If you can master those, then you can easily hit any deer-sized target up to at least 100 m or yd.

6. Loading a Rifle

First, the marksman must inspect the ammo to ensure that it is clean and the correct type for the rifle. Sometimes different rounds can appear identical at first glance. For example, the .300 Blackout is visually similar to the 5.56 (.223) caliber round. They can both easily be fed into an AR platform rifle, but mistaking one for the other can have catastrophic consequences.

Second, the marksman must ensure that the rifle is always pointed in a safe direction. Only then can the marksman open or release the bolt to either eject or load a round into the rifle. If the bolt is not spring-loaded, it must be manually closed.

It is vital to never force a cartridge into a rifle. If the bolt does not fully close, the marksman must clear any obstructions and only then attempt to chamber a new round. Firing a round with a partially closed bolt is extremely dangerous and can lead to an explosion that destroys something or someone.

A common situation for occupational marksmen or hunters who may not have the ability to set up a good shooting support is the need to reload a bolt-action rifle in the prone position. (See Image 64, Pg. 98.) This can be a bit more complicated because the rifle is best loaded without looking so that the marksman can keep their eyes on the target and the wind instead. First, repetition is the best answer. However to make loading easier, the marksman keeps ammo in an easily accessible location allowing them to reload without reaching far. For example, a bag-support can both support the rifle as well as hold ammunition.

Bolt Manipulation

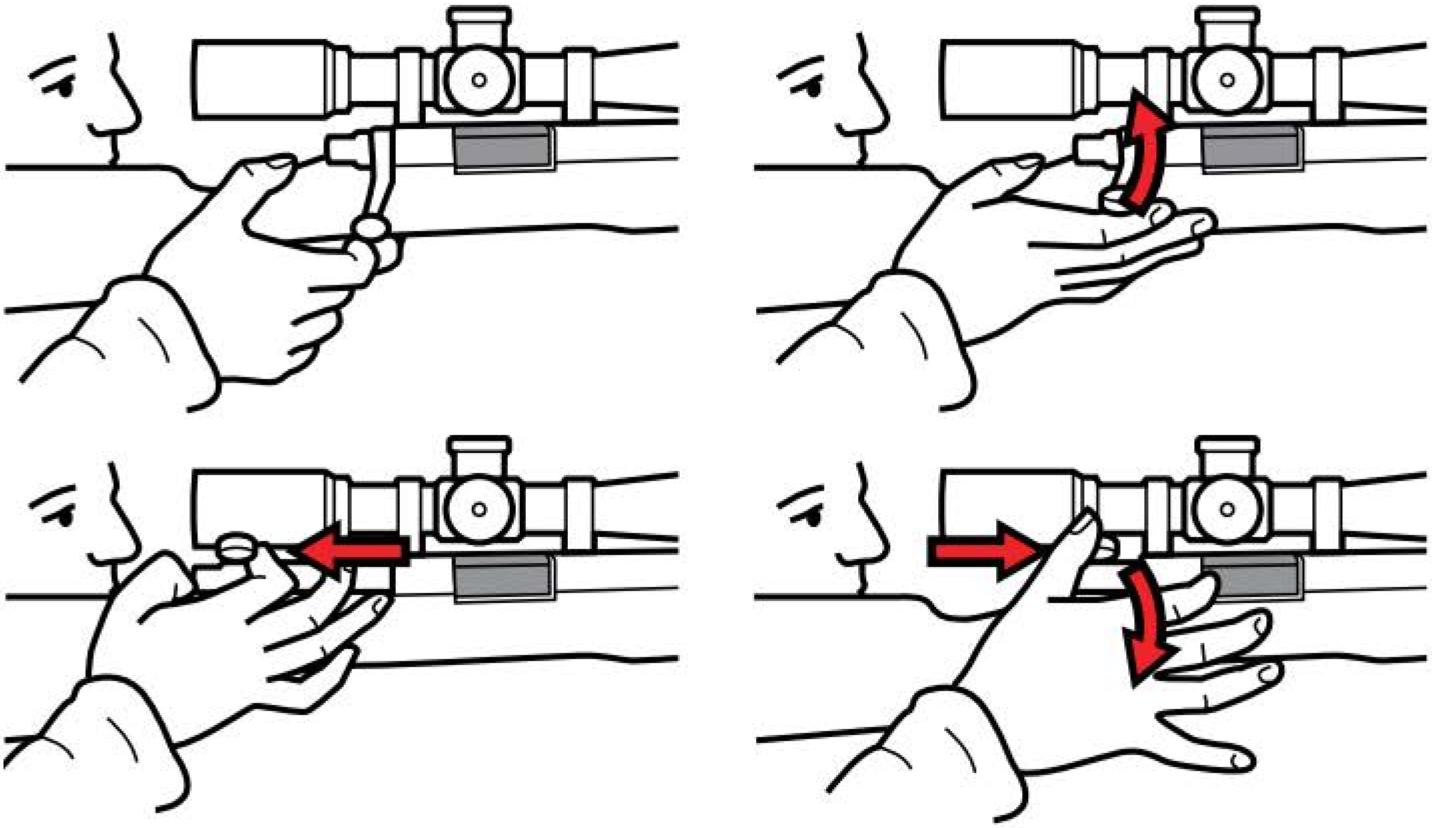


Image 31: The bolt handle of a bolt-action rifle can be quickly and efficiently moved by pushing only with the sides of the index finger and thumb. A firm, smooth upward twist and pull, followed by a push and downward twist do the job.

6.a Bolt Manipulation

Bolt-action rifles require manual reloading, and bolts are manipulated aggressively to avoid issues such as the misaligning of the magazine, which causes rounds to not feed smoothly into the action. Beginner marksmen and those using short-movement bolts often grab the bolt between their thumb and index finger. While this is effective, the marksman's fist may interfere with the scope and require more coordination than a different, better technique. (See Image 31, Pg. 54.) To perform this advanced bolt manipulation technique:

1) The top of the firing hand contacts the bolt knob, pushing it directly up, while the thumb maintains its original position for stability. The palm continues to face the stock even as the knob reaches its highest point, and the thumb remains anchored.

2) The side of the index finger rotates around the thumb to begin pushing the bolt knob rearward, with the elbow and shoulder becoming more involved in the movement. When the bolt reaches its farthest backward point, the spent cartridge is extracted and subsequently ejected.

3) The marksman then pushes the knob forward with their palm or thumb, and the thumb drags the knob down to lock the bolt when it is fully forward. Finally, the hand completes the cycle by returning to the firing position.

7. Taking Aim at a Target

Shooting requires the marksman to have a clear understanding of what they are aiming at. While most rifles are built to be "point and shoot," even experienced marksmen can become even more accurate with a deeper understanding of how to precisely get a target into their crosshairs.

7.a Target Definition

Marksmen must define their targets before aiming at them. While this skill may not be as critical when shooting at paper targets, it is crucial for hunters and occupational marksmen to specify what is and is not a target. For example, hunters aim for the vital areas of animals to ensure a quick and clean kill. Different animals require different targeting strategies because their vital areas are located in different parts of their bodies. (See Image 34, Pg. 56.)

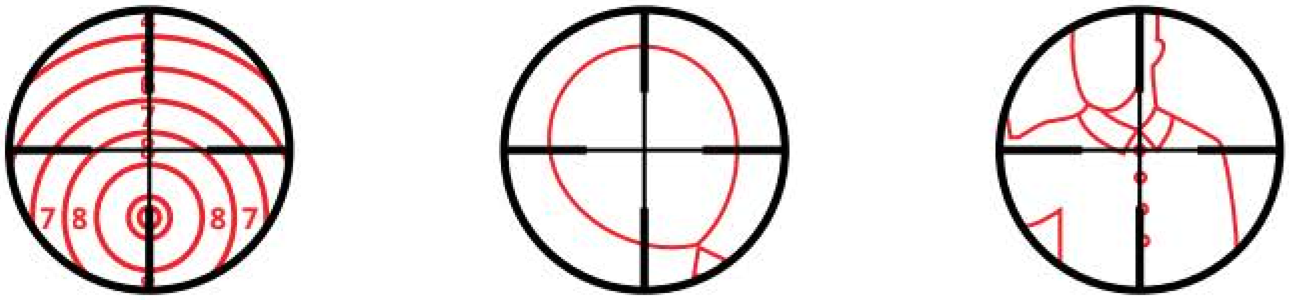
Moreover, marksmen must ensure their targets even qualify as targets in the first place. For example, many states require bucks to have antlers with a minimum number of points before they are eligible to be harvested. And in military contexts, snipers must consider factors such as identifying enemy uniforms and determining if the enemy is wearing body armor.

Regardless of the target, marksmen must always aim for the smallest possible target area, which is summarized by the phrase: "**aim small, miss small**." Redefining the target to something smaller leads to more accurate shooting because marksmen tend to have the same amount of error regardless of the size of their target. Therefore, aiming at a smaller target tends to result in a tighter group of shots.

In practice, this often means **redefining what the target is** to one of the target's vital or central features. For example, aiming at a whole deer is not nearly as useful or effective as aiming for the deer's vital organs, which can be redefined as a hunter's actual target. Aiming at the entire deer and missing by just an inch means missing the entire deer. However, by focusing on a precise point, such as the exact center of the deer, even if the shot misses by an inch, it can still potentially result in a lethal hit. (See Image 32, Pg. 56.)

All that being said, it is essential not to become overly fixated on any specific point of the target, as this may delay the shot. That is because there is a limit to how precisely a marksman can aim due to the slight involuntary movement or oscillation of the rifle caused by factors like breathing, heartbeat, muscle tension, and environmental conditions such as wind. Put another way, aiming at targets smaller than one's natural rifle sway is a waste of time.

Defining a Target

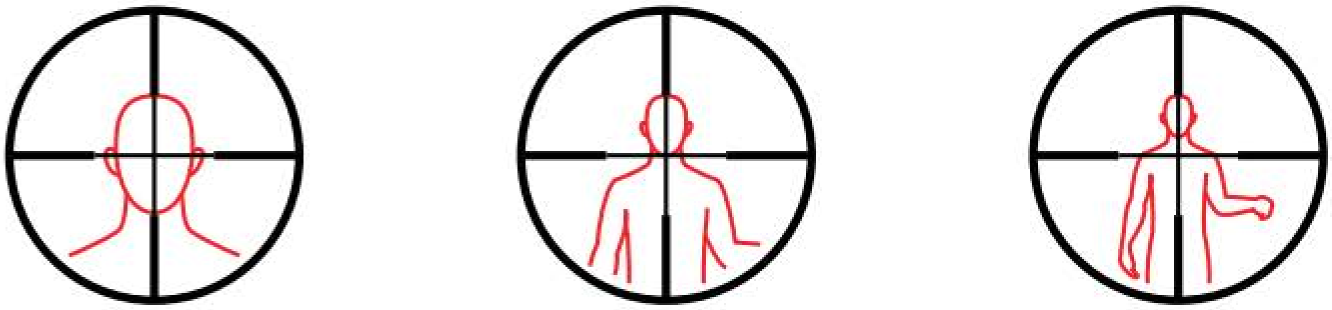


Specific feature: "I'll aim at the 8 on the target."

Nebulous outline: "I'll quarter the balloon."

Proxy feature: "My target is button atop his sternum."

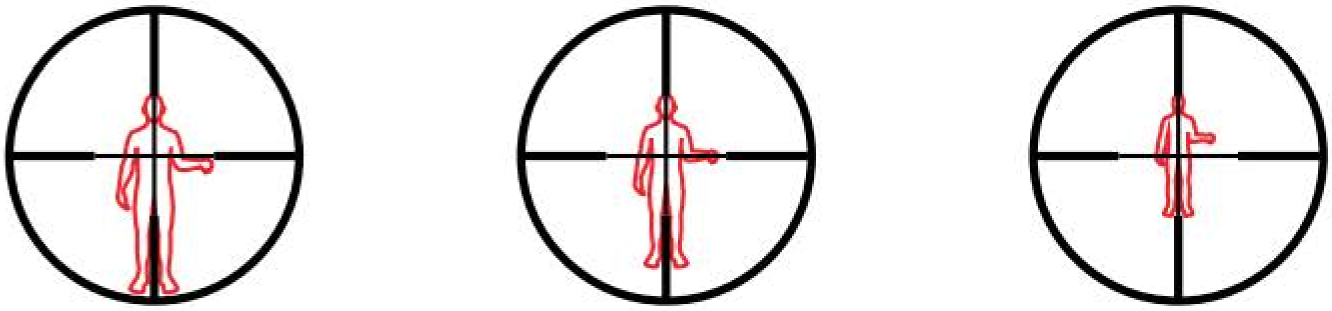
Image 32: **Targets must be as small as possible**. But "small" is only in reference to something else. A marksman creates that reference point in various ways.



100 m or yd: Center of Head

200 m or yd: On Chin

300 m or yd: Shoulder-Level



400 m or yd: Armpit-Level

500 m or yd: Center Torso

600 m or yd: Waistline

Image 33: **Targets appear different at different distances**. Also, shots become less precise with an increase in distance. Therefore, marksmen must use different points-of-aim at targets of different distances.

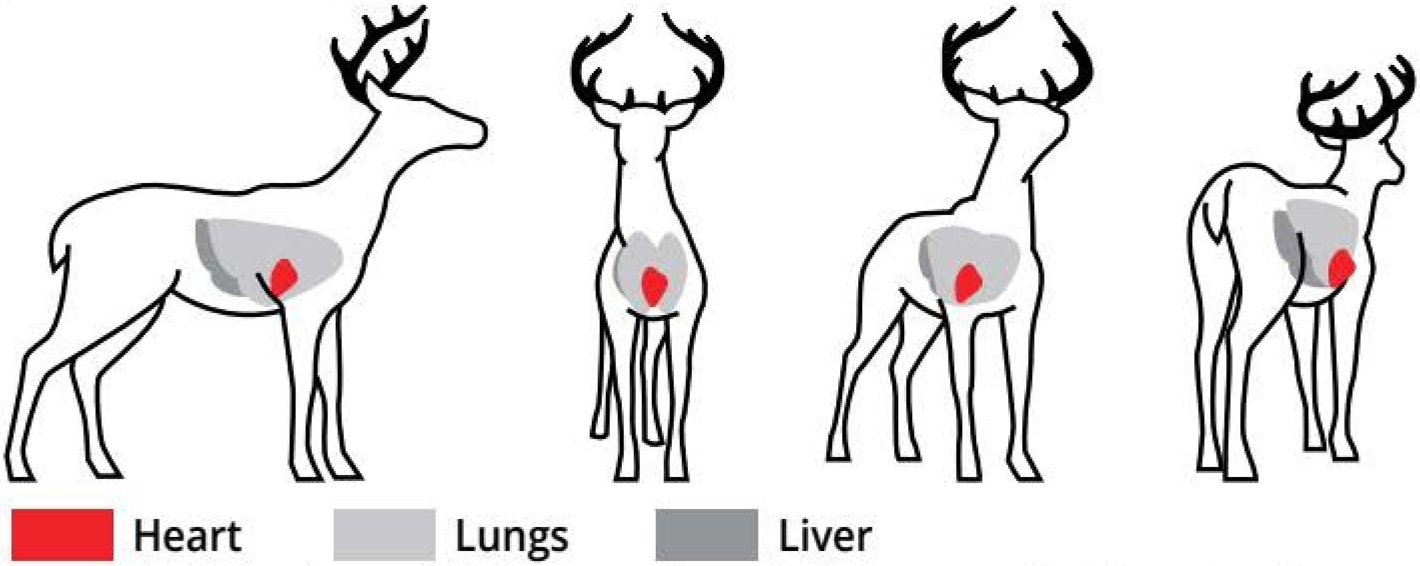


Image 34: Animals are killed faster when vital spots are hit. Therefore, hunters must familiarize themselves with the **proxy locations of vital organs** on the skin.

Search Patterns

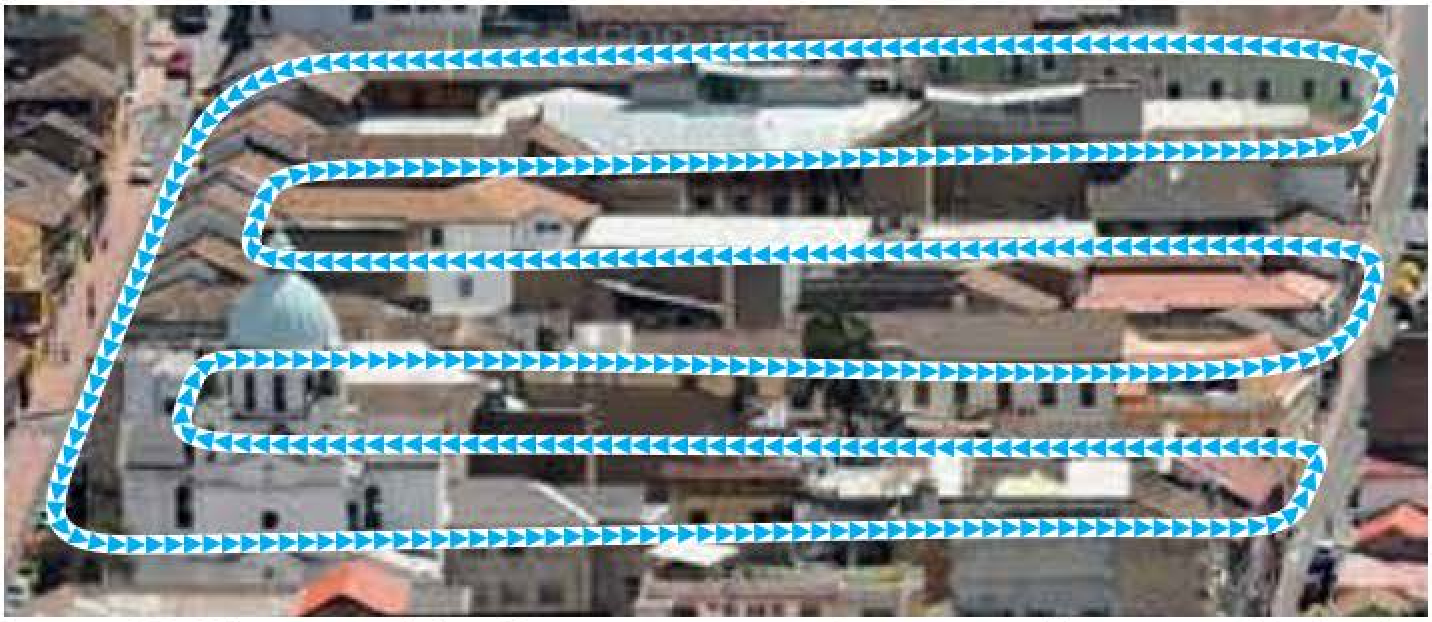


Image 35: When searching for a target, a marksman can be more effective by implementing a search pattern. This pattern follows streets and windows. Many patterns **employ a grid** with an X and Y axis.

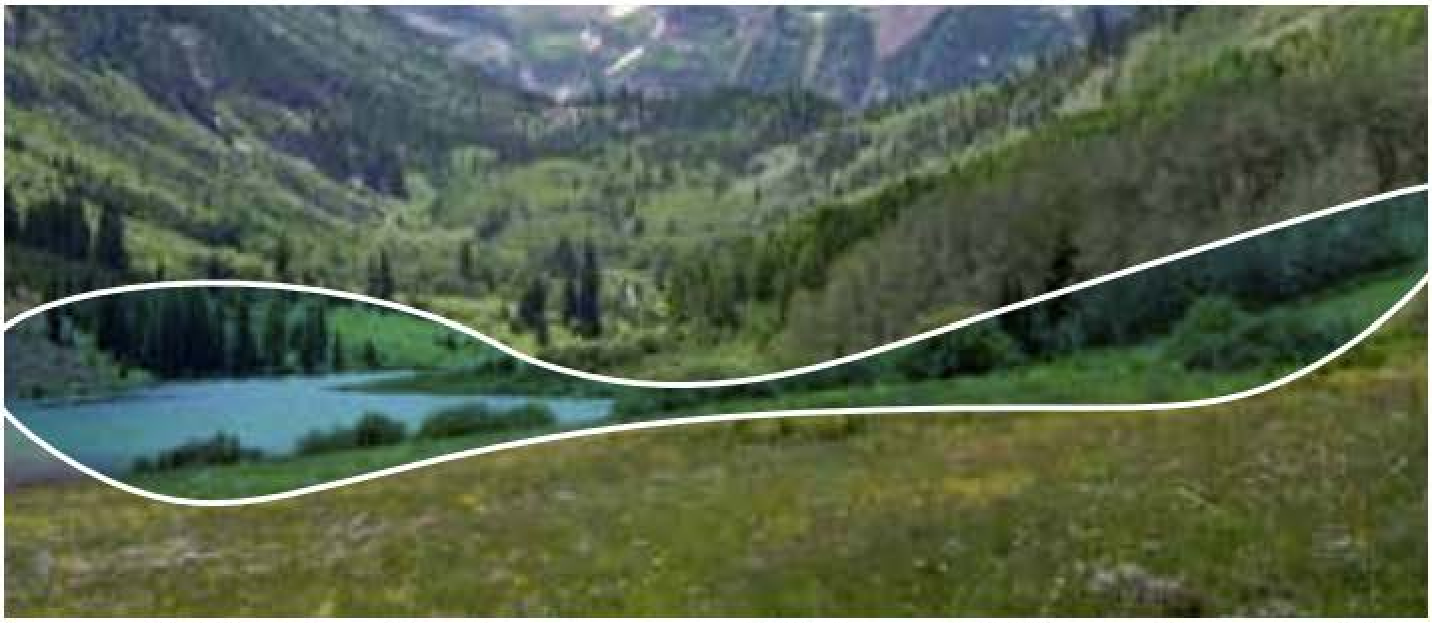


Image 36: Most locations have **areas of high probability** and areas of low probability of finding a target. For example, animals are most likely to appear at the border of woods and meadows, and around bodies of water. Therefore, that is where a marksman's attention is best allocated. Still use a search pattern.

7.b Finding a Target

Once the marksman has defined their target, they can begin to look for it. For target marksmen, this step barely exists, as the target is right in front of them. However, for marksmen with living, moving targets, identifying a target can sometimes take hours or days.

While using the naked eye is always a good default, eyes cannot see as far as rifles can shoot. This is of course why marksmen use riflescopes. However, riflescopes are not the best tool for identifying targets. This is because they must have a lot of space between them and the marksman so that the recoil impulse of a rifle doesn't smash the scope into the marksman's eye. (I.e., eye relief, (See Image 28, Pg. 49.)) This distance apart makes the scope's sight picture take up a smaller amount of the marksman's vision than other, closer optics, such as a spotting scope or binoculars. (See Image 40, Pg. 61.) Once a target is identified with one of these tools, only then does the marksman switch to their scope.

When a marksman is using independent optics for target identification, they must have a plan in place to transition to their rifle once the target has been located. For example, they can prepare their rifle by placing it out of a window prior to starting their search. Alternatively, if walking through the woods, a hunter may choose to walk close to tree branches to provide support for their shot. Failing to do so may result in having to take an important shot from an unsupported standing position, which is less stable and more prone to wobbling. (See Standing, Pg. 100.)

Regardless of the devices a marksman may use, searching with **a system is always optimal**. Specifically, the marksman can define a viewing zone with limits and sweep their sight in a back-and-forth pattern, starting from near to far. (See Image 35, Pg. 57.) It is even more effective for the marksman to focus on areas they know the target frequents, such as a border between fields and woods, near water sources, or entrances and exits. (See Image 36, Pg. 57.)

7.c Sight Alignment and Iron Sights

A sight is a tool that a marksman looks at to help aim a weapon. Scopes are a kind of sight, but there are many other kinds of sights too. One such sight system is the iron sights system. These sights are antiquated and never used by modern marksmen for serious shooting because scopes that are properly calibrated for parallax do not need further alignment. (See Parallax (Reticle Shift), Pg. 34.) Iron sights also significantly obstruct the target and also lack magnification.

That being said, many teachers laud iron sights as a teaching tool because they force students to keep their rifles straight while firing. Iron sights also serve as excellent backup sights in case the scope breaks, loses its zero, or runs out of battery power (in the case of electronic aiming devices).

Iron sights consist of a front sight attached to the front of the barrel, and a rear sight attached to the rear of the barrel. The idea behind iron sights is to place two points (the front sight and the rear sight) along the sightline (the imaginary line between the shooter and the target. If the sights are aligned to the sightline, then the barrel would be aligned to the sightline.

Shooting with Iron Sights

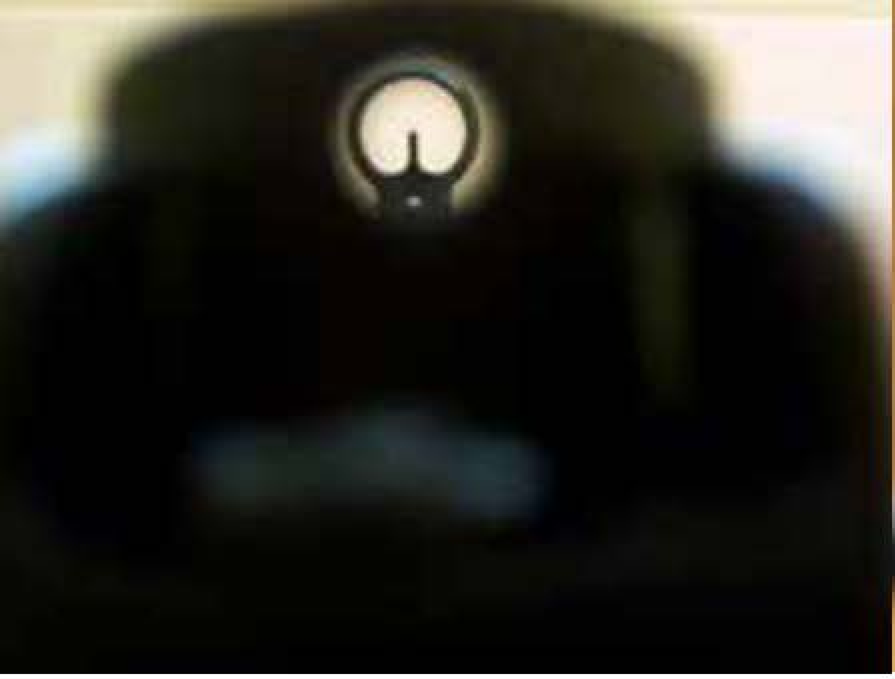


Image 37: The **front sight post** (in focus) can be seen through the **rear sight aperture** (blurry). Keeping the front sight post in focus while shooting maximizes the alignment.

Image 38: A Soldier peers through the **rear sight aperture** (i.e., the post on the right) to see the **front sight post** (i.e., the post on the left) of an M4 carbine. Fort Jackson, SC, 20 Jul 2023.

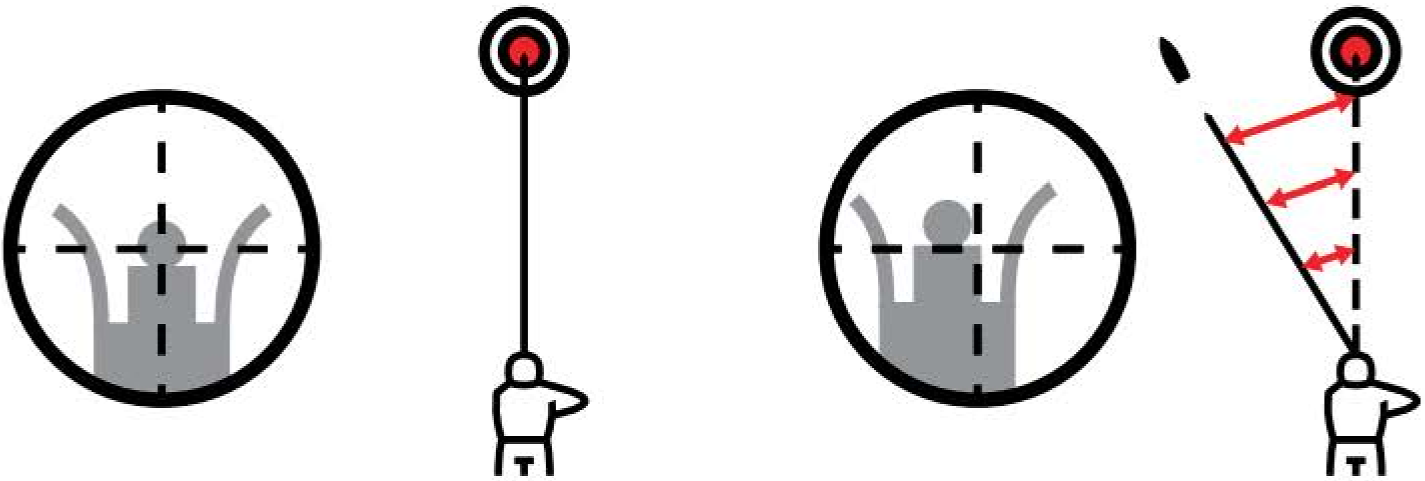


Image 39: The front sight post must be aligned in the center of the aperture to ensure that bullets are put on the correct (zeroed) trajectory.

In other words, "sight alignment" is to align the eye, the front sight, the rear sight, and the target in one straight line. If any of the four points is misaligned, a bullet cannot travel from the rifle to the target. (See Image 39, Pg. 59.) Any error in sight alignment is proportional to the distance, so a 1 cm (0.39 in) error at 25 m (27 yd) is equivalent to a 10 cm (3.9 in) error at 250 m (274 yd).

All iron sights are designed to allow the marksman to center (referred to as a "center hold") the front sight (e.g., thin metal lines or beads) within the rear sight (e.g., a half or "open" sight, or full circle, "aperture" sight). (See Image 37, Pg. 59.) Some marksmen find it helpful to mark the top of the front sight post with a bright dot for enhanced visibility through the rear sight.

Even for identical iron sights, the proper vertical alignment of the front sight within the rear sight can vary according to the marksman's preferences and how each marksman zeros their weapon. For example, a common issue with iron sights is that the front sight post is opaque, obstructing the target when properly centered within the rear sight. Some marksmen prefer to zero their rifle (See Zeroing, Pg. 79.) so that the bullet impacts slightly above the front sight post, allowing them to aim with a slightly lower front sight post (known as a "six-o'clock hold"), which reveals the point-of-impact during aiming. The downside of the six-o'clock hold is that it can be challenging to consistently achieve the exact same point-of-aim every time, making it far more suitable for hunting large game than for precision target-shooting.

To align iron sights, a marksman performs the same zeroing procedure as they would for any other optic. (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.) Different iron sights are adjusted in different ways. Many rifles have rear apertures that can be adjusted for windage and elevation, while others (such as the M16) have both front and rear adjustable sights. It is important to read the instructions and understand the specific rifle being used.

7.d Sight Picture

A sight is a tool that a marksman looks at to help aim, and a "sight picture" is what the marksman sees when looking through or at the sight. For example, the sight picture of a scope is the image seen through the back of a scope. (See Image 9, Pg. 19.) For iron sights, the sight picture is simply what the naked eye sees with the aligned sights at the center of the marksman's vision.

The clarity of the sight picture is influenced by the dominance of the marksman's eye (See Shooting with Both Eyes Open and Eye Dominance, Pg. 92.), external conditions, and the ocular focus of their eye.

The most important external condition to consider when shooting is ambient lighting. Shooting a rifle in low-light conditions is extremely dangerous, so marksmen use night-vision tools. Shooting in extremely bright lighting is also a concern because it can cause eye strain and fatigue. Specifically, focusing on a target in bright sunlight for extended periods can result in a temporary afterimage of the sight picture imprinting on the marksman's retina. To mitigate the effects of bright light, marksmen must look away every few seconds or between shots to allow their retina to clear the afterimage. They can also partially cover the end of the scope to dim the sight picture. (See Image 165, Pg. 193.)

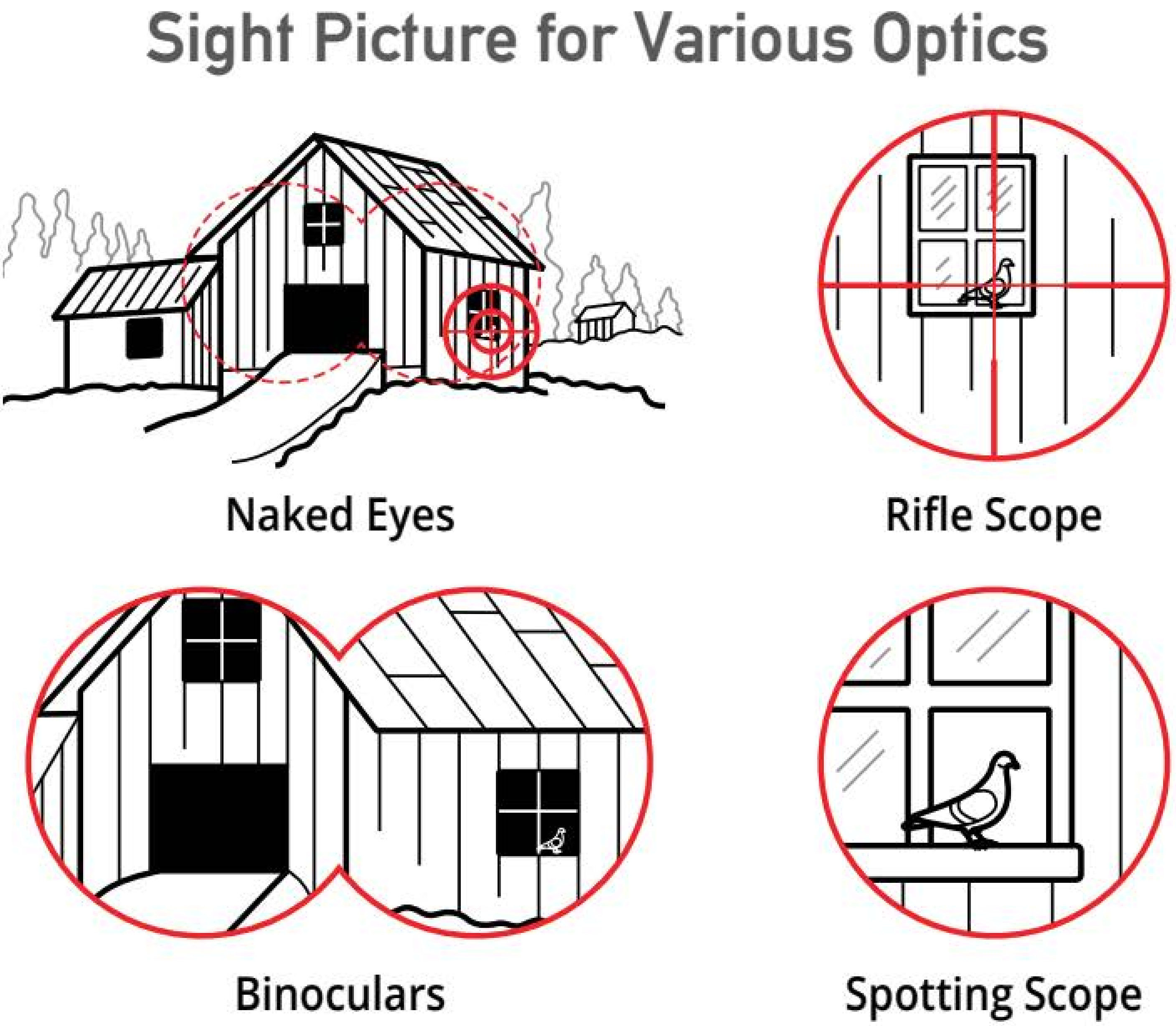


Image 40: **Marksmen typically use multiple optical devices when shooting.** This is because each device has its own advantages and disadvantages. Hunters use binoculars for the widest field-of-view and binocular vision. Target marksmen use a spotting scope (a small telescope) for very high magnification. Both devices can serve as better optics than riflescopes in their niches because they can be much closer to the marksman's eye than a riflescope. Were a riflescope to be close to the eye, the scope would hit the eye during firing because of recoil.

When looking at things far away, things close up become blurry and vice versa. This is because eyes (like scopes and in fact all optical devices) can only focus at a certain range at any one point in time. This range is called the "depth-of-field." (See Image 41, Pg. 62.) This means that when looking through a scope, the marksman's eye can keep the target in focus and the reticle blurry, or the reticle in focus and the target blurry.

When a marksman is searching for targets, they keep the reticle blurry and focus on the target area for two reasons: to better detect any targets that may appear and also to know where to aim. However, when a specific, small target is in a marksman's sight, they switch to the reticle being in focus and make the target blurry. (See Image 37, Pg. 59.) The marksman must actively engage their eye muscles to ensure that their **focus remains on the**

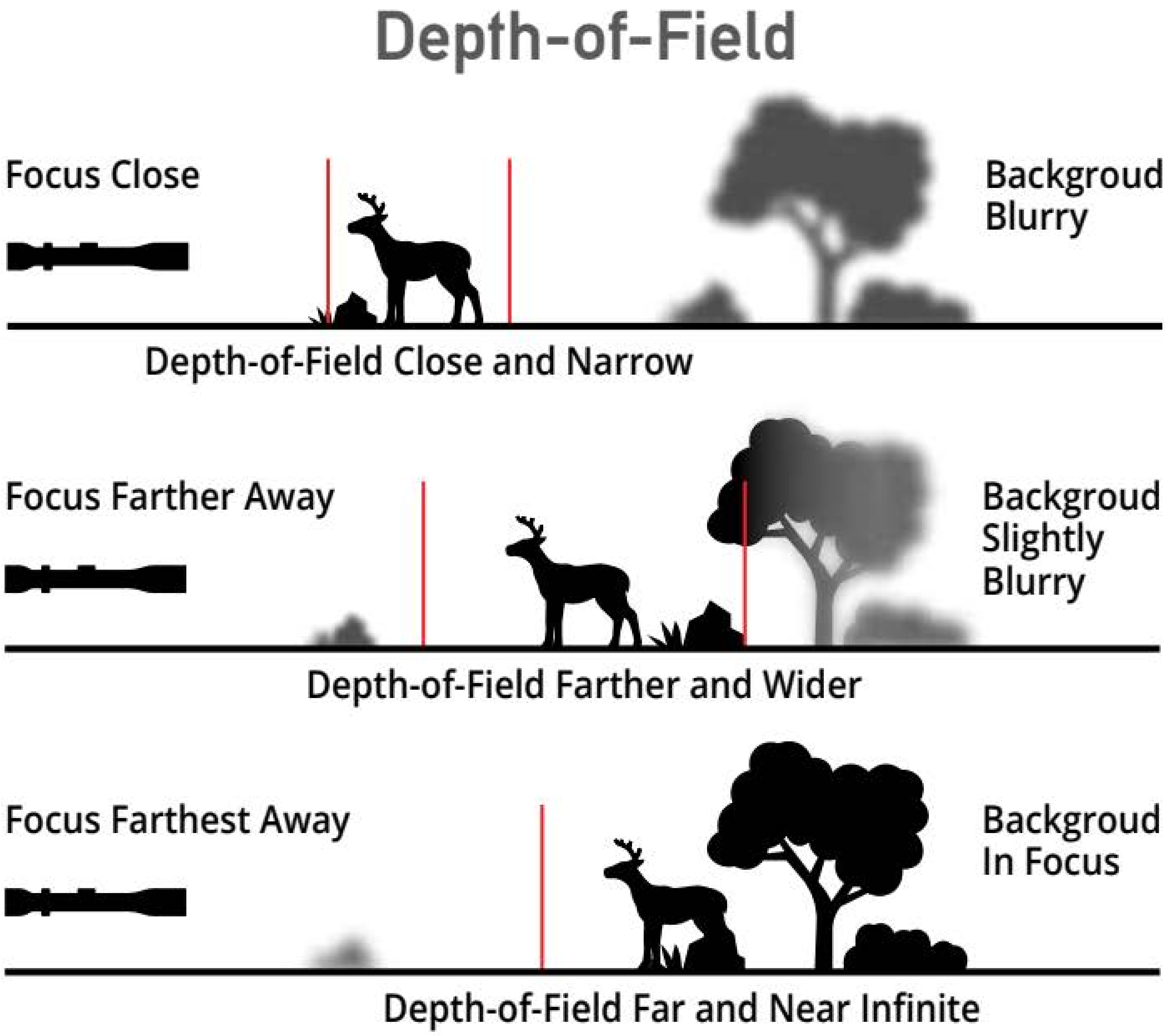

Depth-of-Field
Focus Close
Backgroud Blurry
Depth-of-Field Close and Narrow
Focus Farther Away
Backgroud Slightly Blurry
Depth-of-Field Farther and Wider
Focus Farthest Away
Backgroud In Focus
Depth-of-Field Far and Near Infinite

Image 41: Depth-of-field describes what part of an image is blurry and what part is in focus. If an observer puts a near object in focus, then the depth-of-field is narrow, and therefore, only a narrow depth is in focus. However, **as distance to the observer increases, so does the depth of the in-focus area**. Human eyes also have depth-of-field (as does every optical lens), but the eye's lens constantly adjusts the eye's focus and depth-of-field. It does so very rapidly; so much so that people don't even notice. However, this effect can be observed by putting one hand close to the face and another far away and focusing quickly between them. They cannot both be in focus simultaneously.

reticle or the front sight post. This is because an in-focus reticle is smaller and therefore more precise than a blurry reticle, and a more precise reticle leads to more precise shooting.

Many novice marksmen are hesitant to shoot at blurry targets and instinctively want to focus on what they are shooting at, rather than the measurement tools. However, shooting with thin reticles is far more accurate than trying to discern the precise details of the target. Furthermore, most targets require hitting the center anyway, and aiming at the center of a blurred object is nearly as easy as aiming at the center of a clear object.

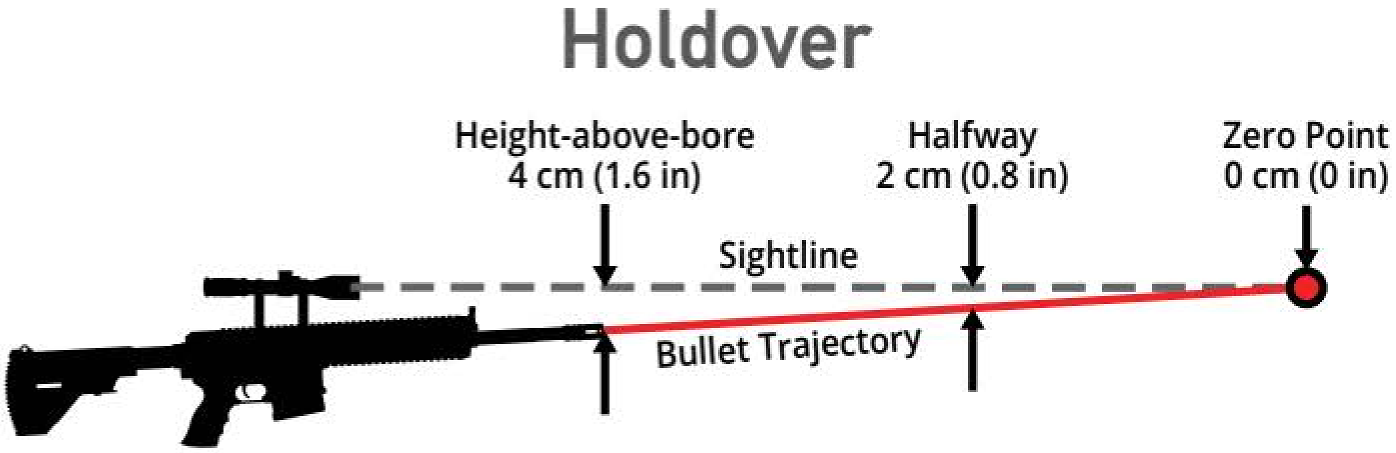


Image 42: Scopes are mounted above rifle barrels. Therefore at the muzzle, the sightline (what the marksman sees) is above the bullet's trajectory. **The sightline and the trajectory intersect at the zero point**. However, before the zero point, marksmen must be aware that just because they can see something through the scope does not mean that their bullet has a clear path of travel.

One technique to help marksmen concentrate on their sights is to make the reticle or front sight more visually appealing, such as by buying an illuminated reticle or adding a dot of red paint to the front sight post so that it would stand out more against the background. Then that sight can be contrasted by using blank, uninteresting pieces of paper as targets.

That being said, some marksmen still prefer to focus on a point midway between the sight and the target, which slightly blurs everything. Others choose to focus on the target area during low-recoil shooting so they can observe the impact of their shots in case they miss the target. This is acceptable for practice, but when accuracy is crucial, it is essential to maximize the chances of hitting the intended target by focusing on the reticle or front sight.

7.e Holdover and Ballistic Loopholes

The vertical distance between the center of the bore and the center of the scope is referred to as the "height-above-bore" or "holdover," which is usually no more than 10 cm (4 in). In other words, bullets obviously exit below the scope because the barrel is below the scope. To compensate for this difference, bores are slightly angled upward so that a bullet exiting the barrel intersects the scope's sightline. This point-of-intersection is known as the "zero point." (See Image 42, Pg. 63.)

Until reaching the zero point, bullets can be assumed to travel in a straight line. Therefore, the boreline, the sightline, and the height-above-bore form a right triangle, with the height-above-bore being around 10 cm (3.9 in). This means that in front of the rifle, the bullet requires 10 cm (3.9 in) of clearance

Image 43: A Jordanian Armed Forces' 10th Border Guard Force sniper positions with his barrel inside a **loophole** to avoid hitting the wall. Jordan, 25 Feb 2019.

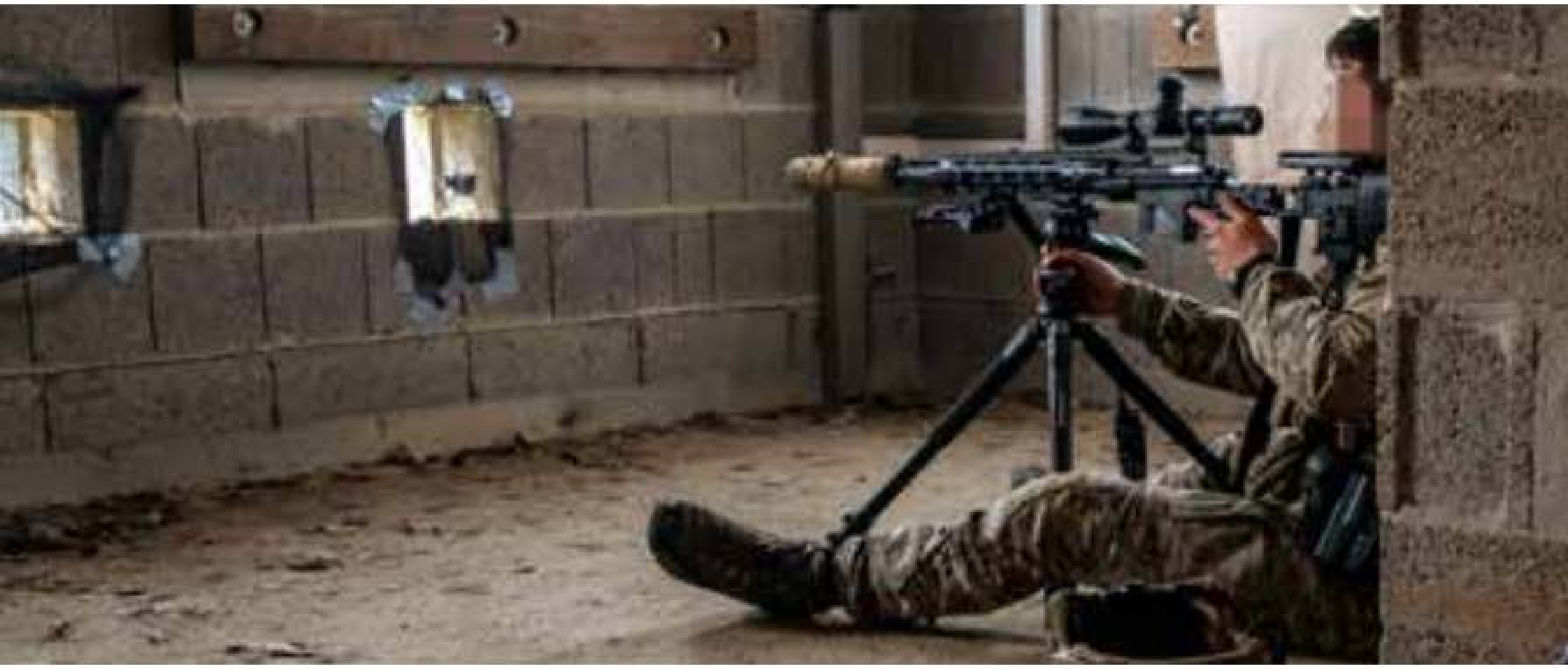


Image 44: A Romanian sniper aims through **loopholes**. If his aim is just above the bottom, his bullet would hit the wall. Hohenfels, Germany, 04 May 2022.

Image 45: A 10th Group Special Forces Soldier fires through **loopholes** to learn to always consider his height-over-bore. Fort Carson, Colorado, 06 Dec 2018.

below the scope. When halfway to the zero point, the bullet needs 5 cm (2 in) of clearance, and when three-quarters of the way, it requires 2.5 cm (1 in).

A mistake that marksmen sometimes make is looking through their scope, seeing a clear sightline to the target, firing the rifle, and then hitting a wall or branch in front of them instead of the target. They mistakenly believe that if they can see the target, the bullet can reach it. However, bullets exit the bore, not the scope. So, **just because the sightline is unobstructed does not mean the bullet's trajectory is unobstructed**.

To avoid hitting anything, the marksman must ensure that every location along the bullet's trajectory is clear. This is not easy to do in a dense forest with many branches; however, if there is only one obstruction, the marksman may be able to open a ballistic loophole, or "loophole." A **loophole** is a hole in a barrier, such as a wall, that allows the bullet to pass through. (Loopholes only work, however, if the marksman intends to aim at a specific point or area.) (See Image 43, Pg. 64.)

Instead of one large hole for both the sightline and the bullet trajectory, marksmen can create space for shooting by making two small loopholes: a top one for the sightline and a bottom one for the bullet to travel through. The loophole is spaced apart by height-above-bore proportional to the distance from the loophole to the zero point. So for example, if the loophole is halfway to the zero point, the bullet's loophole is spaced half of the height-above-bore below the sightline's loophole.

8. Firing the Rifle

After preparing their rifle, positioning themself, and finding their target, a marksman is ready to fire. Immediately before firing, it is crucial to ensure that the **safety is off**. (The safety is on at all other times!) One of the most common errors is to attempt firing with the safety on. To initiate the firing process, the marksman pulls the trigger, experiences and manages recoil, and prepares for any follow-on shots. Once the firing is complete, the marksman must ensure the rifle is unloaded by inspecting the chamber, magazine, and bolt face to confirm that the rifle is empty of ammunition.

8.a Trigger Pull and Flinching

While pulling the trigger, the marksman's focus remains on the reticle. When the reticle is centered on the target, the marksman applies consistent and intentional pressure on the trigger. **The trigger is not tapped or jerked**, and the trigger finger maintains continuous contact. This is important, as using an excessive pulling force necessitates a greater opposing force from the back of the hand or shoulder. And applying stronger forces all around increases the chances of shaking or rotation, which alters the point-of-aim

During the trigger-pulling process, some marksmen prefer to take their time, spending several seconds gradually pulling the trigger, while others do it in a fraction of a second. Some marksmen use a **two-stage trigger**. This type of trigger is pulled until the trigger pull weight changes; pulling beyond that point discharges the firearm. If using a two-stage trigger, the marksman pauses at the start of the second stage to recheck the sight picture (this pause is commonly known as trigger prep or taking out the slack from the trigger). Regardless, the marksman must automatically release the trigger if anything in their visual field changes unexpectedly.

In contrast, some beginning marksmen repeatedly touch and release the trigger, exerting very little pressure without pulling the trigger. They then may repeat that light pull with the application of greater pressure until the trigger is pulled (or jerked) hard enough to discharge the weapon. Such a lack of consistency and focus greatly increases inaccuracy.

Therefore, because the marksman needs to focus on multiple aspects simultaneously (e.g., the sight picture, trigger pull, and avoiding flinching), the skill of properly **pulling the trigger must become somewhat subconscious** through practice. To practice pulling the trigger, a marksman does not need ammunition or targets and can solely focus on pulling the trigger and resetting the action until it becomes muscle memory. (See Dry Firing, Pg. 227.)

Flinching (i.e., tapping or jerking the trigger) is a common involuntary reflex or muscle movement that occurs just before or during the shot. It can range from a forceful jerking of the entire rifle to losing focus on the target completely (a.k.a., “blacking out”). This reflex can be triggered by the anticipation of recoil, a loud noise, any prior negative shooting experiences the marksman may have had, or simply a fear of the consequences of the shot taken. **All marksmen experience flinching.** It can even resurface in expert marksmen who may be experiencing fatigue, stress, or sudden changes in their surroundings. In that vein, even if beginner marksmen start a session without flinching, it is common for flinching to emerge as their body and mind become fatigued.

That said, avoiding flinching can also be achieved through consistent practice, emphasizing proper trigger control and maintaining a stable shooting position. A marksman can also practice with a light-caliber rifle that produces minimal recoil, helping to condition the mind to not associate pulling the trigger with a significant recoil.

To counteract fatigue-related flinching, it is essential to during shooting sessions and ensure proper rest and hydration. Additionally, to prevent mental panic, a marksman can audibly talk themself through the process. By hearing their own words, the marksman compels themself to focus on the present task rather than the future consequences.

Marksmen may be unaware of any flinching that may be occurring and ultimately affecting the shots they have taken. This might be because they experience no flinching during practice where they know they are not firing live rounds, or because the recoil of the rifle masks any flinching when live rounds are present. It is possible to determine the extent of a marksman's pre and post-firing flinching with the help of a useful technique. That is to practice firing with a random mix of live rounds and dummy rounds. Most helpful would be if these rounds are loaded by an assistant so that the marksman does not know the sequence of the rounds present in the chamber. When "firing" dummy rounds, the marksman can then determine if they flinch without the interference of recoil. (See Image 196, Pg. 231.) Even better, the assistant can video-record the shooter in slow motion to determine if there is even a minuscule level of flinching.

8.b Recoil and Muzzle Jump

Recoil (a.k.a., kickback) refers to the forceful, backward movement of the buttstock that occurs after firing a rifle or any other firearm. **Muzzle jump** (a.k.a. muzzle rise) is the forceful, upwards movement of the muzzle after firing. It occurs because the bullet travels through the barrel, above the stock, causing the rifle to rotate about the marksman's grips which serves as a fulcrum (i.e., a center of rotation). (See Image 47, Pg. 69.)

Both recoil and muzzle jump are direct consequences of laws of physics (which are vital to ballistics). Newton's third law of motion states that for every action, there is an equal and opposite reaction. In the context of firearms and long-range shooting, the action is the expulsion of the bullet from the barrel. The reaction is the backward thrust of the rifle into the marksman's shoulder pocket and the rotation of the rifle about the center-of-mass. Any adjustment to the action affects the reaction; an increase in the amount of powder causes a corresponding increase in recoil and muzzle jump.

If strong enough, **recoil can cause discomfort or injury** to the marksman, resulting in fatigue, bruising, or even ineffectiveness. This is common after firing multiple rounds of high-powered ammunition. Additionally, excessive muzzle jump affects the sight picture of the scope between shots. Consequently, various techniques and equipment have been developed to mitigate the effects of recoil and muzzle jump.

There are two types of recoil reduction methods. The first type, **true recoil** reduction, involves creating a counteracting force. For example, muzzle brakes redirect the gas exiting the muzzle to the side. This redirection pushes the rifle forward upon impact with the muzzle brake, counteracting the forces pushing the rifle backward. Similarly, compensators redirect gas to exit from the top-side in order to counteract muzzle jump. (See Image 49, Pg. 71.)

Muzzle brakes and compensators neutralize force equal to the percentage of gas redirected sideways, and double the percentage redirected backward. To illustrate, a .50 Browning Machine Gun (BMG) fires a bullet weighing approximately 700 grains with a powder charge weighing 300 grains. If all of the gases produced by the gunpowder were redirected sideways, recoil would be reduced by 30%. If the gases made a U-turn and were redirected backward, recoil would be reduced by 60%.

Similarly, true recoil reduction can also be achieved by redistributing the force of recoil to rifle supports such as bipods, tripods, or sandbags. These supports absorb and distribute the force to the ground, minimizing the impact on the marksman. When choosing a support, it is crucial to consider its ability to transmit recoil effectively and remain stationary. Any movement of the support between shots indicates improper usage. For example, if bipod legs creep forward, it signifies that the marksman is applying excessive pressure on the rear of the bipod.

The second type of recoil reduction is known as simulated reduction or "**felt-recoil**" reduction. When a bullet is fired from a rifle, Newton's third law dictates that a counteracting force is generated. However, the intensity of this recoil force can be lessened by making the force present over a longer period of time. For example, instead of experiencing a sudden recoil of 1000 newtons of force (~100 kg or ~45 lb of weight on earth) in 0.1 s, the body might perceive a 500-newton force spread over 0.2 s.

For example, adding springs between the marksman and the explosion can extend the duration of the recoil force. Many weapon systems utilize metal spring mechanisms, such as the AR-15 platform which has a buffer and a spring in its stock. Advanced firearm designs may incorporate hydraulic or pneumatic shock absorbers, or even a combination of springs, cams, and levers, to modify, dampen, or dissipate the rearward impulse created when

The Effects of Recoil

Image 46: A Soldier assigned to 40th Cavalry Regiment (Airborne), 4th Infantry Brigade Combat Team (Airborne), 25th Infantry Division, U.S. Army Alaska, absorbs the **recoil** from an M2010 Enhanced Sniper Rifle. Statler Range, Joint Base Elmendorf-Richardson, Alaska, 06 Apr 2018. The muzzle is slightly elevated due to **muzzle jump**. The cheek is being dragged back due to recoil. And the marksman's eyes are closed because of an instinctual reaction to the force.

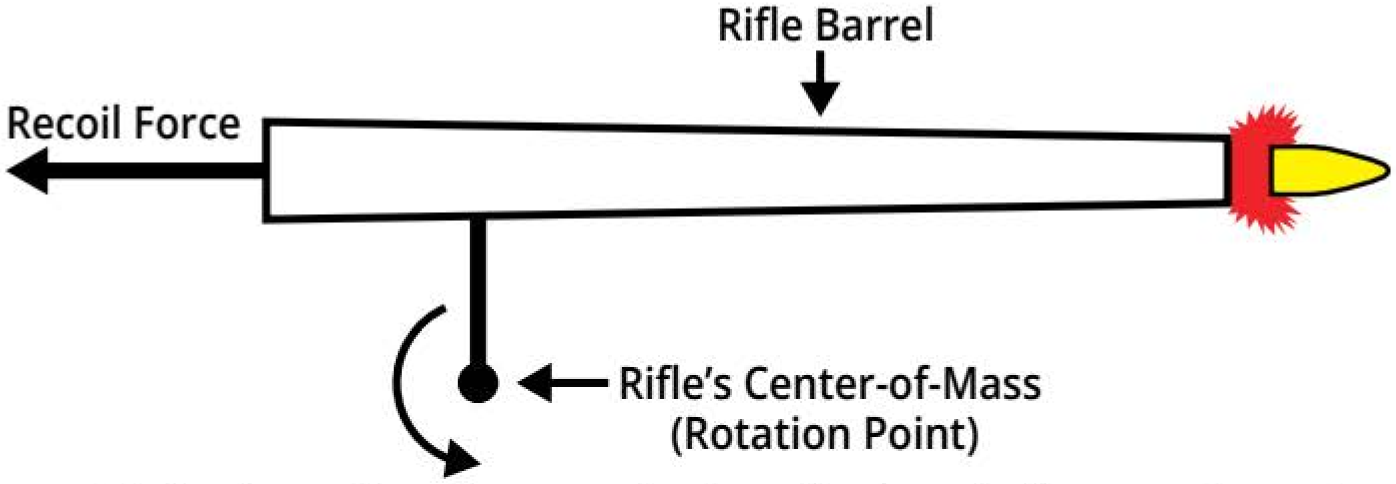


Image 47: The force of recoil presses the barrel backwards. However, the center-of-mass is below the rifle. Any force that does not act through the center-of-mass causes rotation. Because the barrel is above the center-of-mass, it forces the muzzle to rotate up (i.e., muzzle jump) and the buttstock to rotate down.

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the bullet is fired. Each mechanism has its own advantages. For example, gas springs are more expensive but do not have bending metal parts such as coil-type springs that can break.

Interestingly, the primary "spring" used to distribute recoil over time in most rifles is the buttstock pad, also known as a recoil pad. In the context of long-range shooting, the buttstock pad functions as a spring in that when the rifle is fired, the padding compresses and gradually decompresses over a more extended period, extending the shock-of-force over time. Other cushioning materials, such as rubber or even a common sponge, can also be used as recoil padding. These materials can be worn over clothing or integrated into jackets.

In fact, the human body itself also acts as a spring. When the body is positioned in a way that allows it to naturally move with the recoil, the force is spread over a greater distance, giving the force more time to dissipate.

Therefore, marksmen must relax their bodies as they shoot and avoid tensing their shoulders. Similarly, if the marksman does not firmly press the firearm into their shoulder pocket, the rifle can hit the shoulder with more force. This happens because the rifle accumulates backward momentum instead of dissipating that momentum into the shoulder from the moment of firing. (See Shoulder Pocket, Pg. 44.) (See Momentum, Pg. 246.)

In addition to extending force over time, pads also decrease force over area. That is, they reduce pressure. Pressure is determined by the combination of force and area, so pressure can be minimized by distributing the force over a larger area. That is one reason why stock dimensions are so important. Specifically, stocks with a low, sharp comb (where the cheekrests) or a small, hard buttstock-end-plate (i.e., buttplate) concentrate the recoil into a smaller area, thereby increasing the pressure and making the recoil feel more intense. Some marksmen dissipate the force by wearing thick jackets or draping towels over their shoulder pockets. However, they risk filling in the shoulder pocket and making holding the rifle somewhat more difficult.

An alternative to springs that reduces felt-recoil is to increase the mass of the rifle. An object with more mass moves slower when subjected to the same force, while an object with less mass moves faster. This is called "the principle of inertia." Therefore, increasing the mass of the rifle decreases its movement speed for the same force, giving the body more time to adapt and absorb the incoming force and thereby reduce the felt recoil, despite the fact that the true recoil remains unchanged. A simple way to add mass to a rifle is by incorporating a lead weight in the buttstock. The reduction in felt recoil is directly proportional to the mass added; therefore, to halve felt recoil, the marksman would need to double their rifle's mass. That being said, most marksmen prefer lighter rifles because they are less expensive and easier to carry.

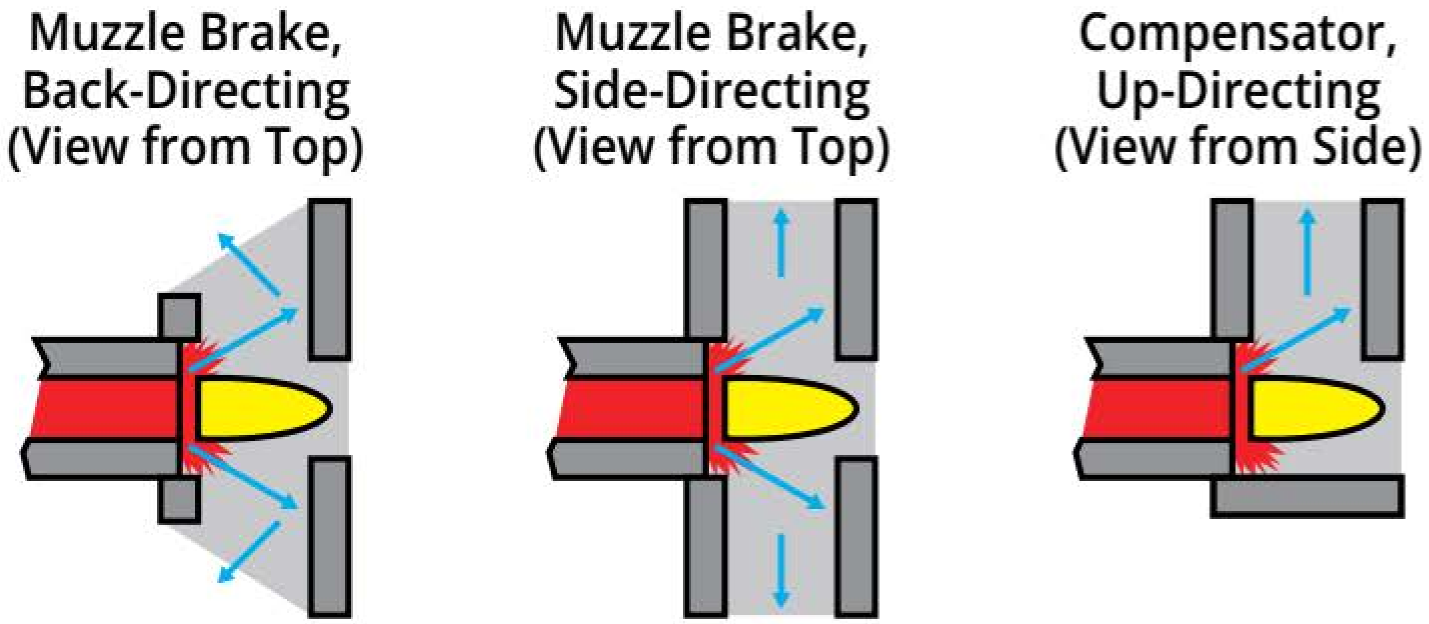
Regardless of the type of recoil or type of mitigation, shooting with and without mitigation requires slightly different techniques. Therefore, marksmen must either mitigate recoil both in practice and in execution or in neither of the two. For example, a target marksman's tournament performance is diminished if they practice with a padded vest but compete without one.

8.c Follow-Through and Reacquiring Sight Picture

"Following through" refers to the act of maintaining a shooting position after firing a weapon until after the recoil pulse has subsided. This includes

Muzzle Brakes and Compensators

Image 48: An Iraqi security forces soldier fires a Steyr HS .50 anti-materiel rifle. The rifle has a muzzle brake (back-directing) to reduce the intense recoil of a .50 round by forcing gases to exit from both sides to cancel out each other's force. Camp Manion, Iraq, 29 Mar 2017.



Muzzle Brake, Back-Directing (View from Top)

Muzzle Brake, Side-Directing (View from Top)

Compensator, Up-Directing (View from Side)

Image 49: Muzzle brakes that **redirect gas** backwards counteract recoil by pushing gas in the opposite direction of the bullet. Muzzle brakes direct the gas sideways to neutralize the force of gas by pushing it to either side equally. Compensators counteract muzzle jump by **forcing gas upwards**. These devices do not reduce a bullet's velocity because they only affect gas that has already left the barrel.

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holding the trigger to the rear and delaying a trigger reset. (See Image 50, Pg. 72.) Follow-through serves a few important purposes:

1) It reinforces the mental habit of trigger control, allowing the marksman to focus on the present shot rather than any future shots.

2) It enables them to pay more attention to detecting any inadvertent flinching that may be occurring.

3) It ensures that the shooting process ends with a still position rather than a moving one (i.e., reengaging). If a marksman plans to move after the shot,

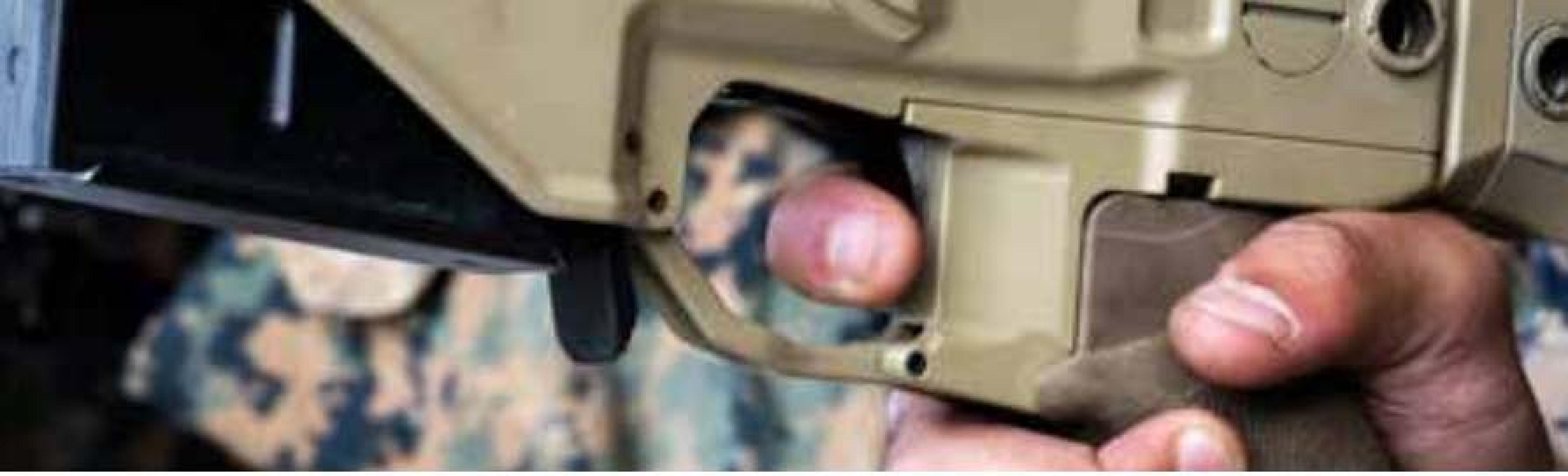


Image 50: A U.S. Marine with 3d Reconnaissance Battalion, 3d Marine Division, holds the trigger to the rear after firing. Camp Hansen, Okinawa, Japan, 27 Jan 2021.

they are more likely to move during the shot, whereas planning to remain still after the shot increases the likelihood of staying still during the shot.

4) It allows the marksman to quickly reacquire their sight picture. Recoil from the firing sequence may cause the sight picture to move off the target, but reducing the number of inputs (such as resetting the trigger) can lessen the movement of the sight picture. Marksmen must aim to see their target again as soon as possible. (Even if the marksman does not intend to take follow-on shots after any one particular shot, it is always necessary to reacquire the sight picture after every shot in order to develop a consistent habit of following-on.)

The possibility of the fourth point, reacquiring the sight picture, depends on the power of the ammunition. On a low-recoil firearm (such as a .22 LR rifle), the marksman can maintain the same sight picture throughout the shooting process with good follow-through. However, if the recoil is medium-to-high, it causes marksmen to lose their sight picture after firing no matter what. Therefore, marksmen prepare by remembering their current sight picture and matching what they see to the previous one. They may also lower the magnification setting to get a larger sight picture if they have to shoot at the same target multiple times. Finally, marksmen rely on their proprioception (i.e., the sense of knowing where body parts are) to learn and remember their body position. This allows them to accurately reposition their body after firing, returning to the same stance they recall. These techniques to reacquire the sight picture require full focus and are rarely exact.

Once the marksman has consciously executed a follow-through, the trigger is smoothly reset to the firing position and the next round is chambered. Again, performing a smooth reset is faster overall compared to rushing through the whole firing sequence.

8.d Cold-Bore Shooting

A “cold-bore shot” refers to the initial shot fired from a firearm during a shooting session. Because the act of firing a firearm burns gunpowder, the first shot as well as all subsequent shots heat the bore. This means that the first shot always occurs when the bore is at its coldest, hence the name.

Historically, professionals and other long-range shooting specialists have justified the existence of the cold-bore shot with the concept of thermal expansion. Thermal expansion occurs when materials expand due to temperature changes. In the case of steel barrel rifles, the barrel expands and changes shape as it heats up due to the energy and heat expended by exploding gunpowder (propellant). In sum, a cold barrel is physically a slightly different shape than a hot barrel.

However, the expansion does not continue forever. Air surrounding the heated barrel cools and contracts it back down to the ambient temperature over time. Therefore, through a consistent cycle of shooting, the burn of each round and the subsequent air cooling theoretically reaches a quasi-equilibrium, in which the barrel remains within a range of temperatures and sizes. The logic is that the cold-bore shot is performed with a barrel that is the farthest outside this range of barrel size and expansion, and is therefore most affected by it.

This logic is not completely incorrect. Thermal expansion does occur; however, it does not significantly contribute to the inaccuracy of only the initial shot. In simple terms, each round fired from a rifle increases the barrel’s temperature by a similar amount. When shooting rapidly, the barrel continues to heat up because the air does not have enough time to cool it. If temperature were the primary cause of the initial inaccuracy, it would continually affect the point-of-impact for every shot. Furthermore, while the predictable and repeatable nature of metal’s thermal expansion theoretically suggests that it would cause consistent cold-bore shots, many marksmen find that their cold-bore shots deviate away from their point-of-aim in different directions each time, to varying degrees.

Another speculated factor that may affect the trajectory of the first bullet fired from a cold bore is the residue left in the barrel from previous shooting sessions. However, although this phenomenon is also genuine, it does not have as significant an impact on the point-of-impact as marksmen often report when experiencing a cold-bore shot.

The only plausible cause of the infamously inaccurate cold-bore shot is that **marksmen tend to flinch in anticipation of recoil** more on their first shot of the day than with subsequent shots in their session. In other words, the first shot of many is typically the least comfortable. A test to confirm this can be done by having a marksman fire two rifles, one after the other.

Tested marksmen generally find that the cold-bore shot only occurs with the first rifle and not when they switch to the second, which is also technically being shot cold. The best solution to overcoming the "cold-bore" shot is dry-firing practice prior to moving to live rounds. (See Dry Firing, Pg. 227.)

9. Ensuring Accuracy (Grouping and Zeroing)

Rifles can be highly precise instruments. But they must be calibrated so that scopes can accurately predict where bullets impact. To align where the bullet goes (i.e., the point-of-impact) to what the marksman sees (i.e., the point-of-aim), marksmen perform a process known as "grouping and zeroing."

In short, grouping is to fire a series of rounds together as a group at the same point-of-aim. A "grouping" on a target is simply a group of shots. "Zeroing" is to calibrate the rifle off of a group by adjusting the scope so that following shots are more accurate. By iteratively grouping and zeroing, a marksman can bring together their point-of-aim and point-of-impact.

Before grouping and zeroing, a marksman must always verify that all parts of their weapon system, particularly the scope, **are securely fastened** to make the rifle as repeatable as possible. Furthermore, when using a rifle for the first time, a marksman may benefit from firing a few times to become familiar with their rifle's recoil and grouping patterns.

9.a Grouping

Grouping is both a verb and a noun. The act of "grouping" refers to firing several shots at a target as closely together as possible. The result is a tight "group," "shot group," or "grouping" of impacts. The number of shots in a group is up to the marksman. While some marksmen prefer to use three-shot groups to save ammunition, others prefer five-shot groups for a more accurate average.

The tightness of a group depends on many factors. Just one example of that is that some rifles are more accurate with certain brands and types of ammunition. The properties of ammunition that can influence group-tightness include: the material of the projectile (copper jacketed or lead), the shape of the projectile (wad cutters, semi wad cutters, round headed), the weight (grains), the amount of propellant, and the amount of variability from one cartridge to the next. This is partly why 'match grade' ammo exists; it is designed to be more accurate than regular ammo.

The purpose of grouping is to find the center of the group, which is the average point-of-impact. The average is the best estimate a marksman has of where a rifle would shoot without variation or external influence.

"Average" can have two different meanings. When measuring the performance of a rifle, the "average" is the distance between the centers of the two farthest shot holes in a group (hereafter, referred to as the "**diameter**"). On the other hand, when trying to find the expected point-of-impact without random or environmental influences, the "average," or "**center average,**" is the central point of the group of shot holes. (See Image 52, Pg. 76.)

The center average of a group provides an estimate for the distance between the marksman's point-of-aim and the rifle's point-of-impact. Due to the randomness of individual shots and the influence of the marksman, the actual difference between these two points remains somewhat uncertain. However, a tight group improves the accuracy of the estimated distance and direction.

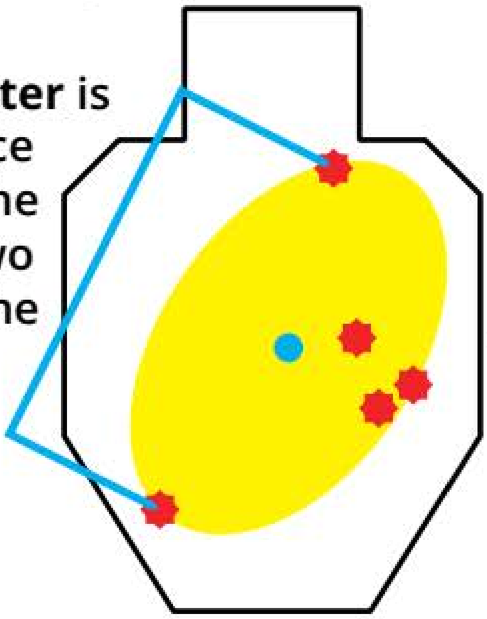
When shooting multiple groups on the same target, the marksman can differentiate between them by using a different color marker to connect all the bullet holes in each group. Alternatively if one marker color is available, the marksman can use different kinds of lines: solid, dotted, dashed, etc. A dot or mark is then made to indicate the group's center, and a number is written alongside each group. (See Image 51, Pg. 76.)

As a general guideline, groups larger than 0.5 mils (2 MOA) in diameter (See Angular Distance, Pg. 237.) using a minimum of three rounds are not precise enough to base adjustments on, and are therefore invalid. While there is no specific lower limit for acceptable group size, groups between 0.25 and 0.5 mil's (1 and 2 MOA) are typically sufficient as most marksmen and rifles simply cannot achieve groups tighter than 0.25 mil's (1 MOA, or a "sub-MOA rifle") even in ideal conditions.

Considering that groups have a limit to how small they can get regardless of the marksman's skill level, one common mistake marksmen make is fussing too much over their aim. The inherent inaccuracy in equipment is precisely why marksmen must rely on the average of a group to make sight adjustments

Grouping Bullet Impacts

Image 51: This marksman made a **group of 5 shots**, and marked them in three distinct ways. First, they circled each hole. Second, they connected the holes. Third, they found the center average of the group and wrote down the number of the grouping (in this case "1"). They can also use a different colored marker for each group to distinguish them from each other.



The **diameter** is the distance between the farthest two points in the group.

The **center average** is the most central point of the grouping (usually estimated), represented here as the center of an ellipse fit to the grouping.

Image 52: There are two common measurements of a group: the diameter and the average (a.k.a., center average).

in the first place. (See Inherent Imprecision, Pg. 198.) Another mistake is to adjust the point-of-aim from the first shot in the group to subsequent shots. **Every shot in a grouping must have an identical point-of-aim for the group to be valid.** A third mistake is to believe that an exceptionally tight group represents the true precision of a rifle. It is not uncommon for a few shots to randomly deviate in the same direction.

It is okay to disregard problematic shots (i.e., outliers or "fliers") at any point during the zeroing process since the point of grouping is to assess the equipment, not the marksman. If a shot feels off during shooting, the marksman can fire an additional round so long as the marksman knows which bullet hole is being excluded when they assess their grouping. When shooting with a spotter, the marksman must promptly notify the spotter of any bad shots, and the spotter must inform the marksman of any inaccuracies that they may see on the target.

9.b Picking a Zero Distance

While light travels in a straight line, bullets follow a curved path. As a result, the trajectory of a bullet intersects with the sightline of a scope at two specific points (i.e., "**zero points**"). In other words, a zero point is where the point-of-aim (as seen through the center of the reticle) aligns perfectly with the point-of-impact (where the bullet hits its target). (See Image 53, Pg. 78.)

(When shooting at distances greater than 500 m or yd, it may be beneficial for the marksman to not base their zero point off of the center of the reticle, but instead slightly above the center to allow for a longer vertical distance below their point-of-aim. This extra vertical distance allows a bullet to fall farther before exiting the sight picture.)

There is one zero point where the bullet is rising and nearer to the marksman, the "**near-zero point**," and another when the bullet is falling and farther from the marksman, the "**far-zero point**." (If the apex of the bullet trajectory is exactly tangential to the sightline, there could in theory be one zero point, but that is very rare.)

While a zero point is the location of the intersection between the point-of-aim from the center of a reticle and a bullet trajectory, a **zero distance** is the distance between the marksman and a zero point. The center of a reticle does not match the point-of-impact except at the two zero distances, and therefore the marksman must use another location on the reticle as their point-of-aim.

Zero distances, just like zero points, come in pairs: one zero distance for each zero point. In theory, using the far zero distance is preferable since the bullet only falls after the far zero, instead of rising and falling as with the near zero distance, and so calculating the total vertical difference between the sightline and the bullet's impact location (i.e., bullet-drop) is easier. However, in practice, the difference is accounted for when bullet-drop tables or ballistic calculators are used anyway. (See Ballistic Calculators, Pg. 221.)

In theory, a rifle could be calibrated to have a zero point at any distance as long as it can shoot that far. But most marksmen choose a zero distance based on the distance at which they are most likely to be shooting. Thereby, **shooting is easier because the marksman can often use the center of their reticle to predict where their bullets impact on the target.**

Zero Distance

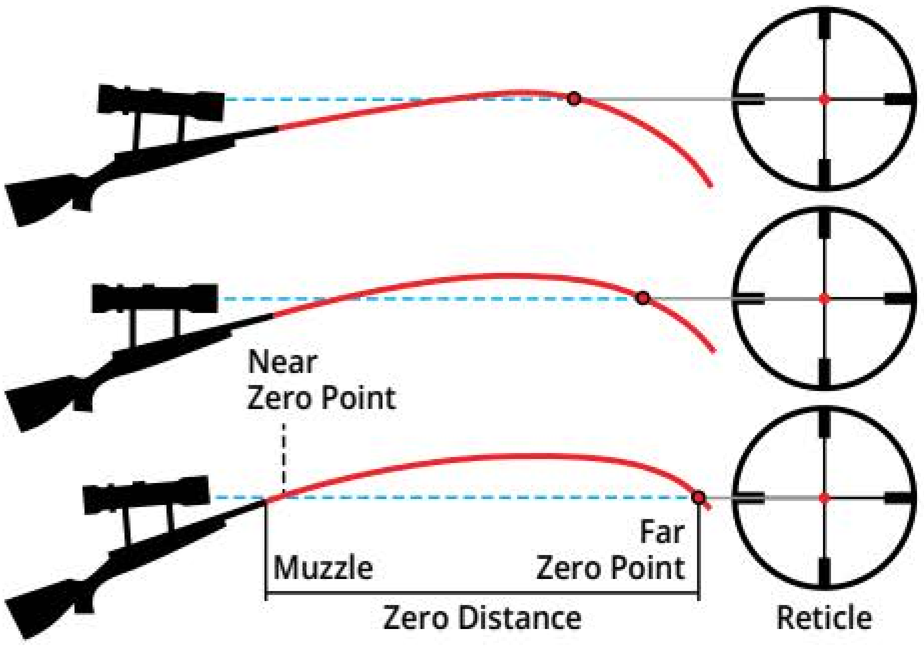


Image 53: The sightline (dotted line) intersects with the boreline (curved line) at two points. The far intersection is known as the “far zero point,” or usually just the “zero point.” In all three diagrams, the bullet’s trajectory is about the same; however by adjusting the reticle up or down, the marksman can extend out the far zero point because the bullet has to travel further to meet the sightline again. The distance from the marksman to the zero point is the zero distance. In sum, a marksman can **adjust their reticle elevation** to attain their desired zero distance.

Typical zero distances can range from 25 to 300 m or yd. However, the exact distance depends on the individual marksman’s specific needs. For example, a marksman in a dense forest may not shoot at targets beyond 100 m or yd, while a plains hunter may frequently engage targets over 300 m or yd away. An extreme-long-range marksman could theoretically use a zero distance of 1000 m or yd, although they are much more likely to use something closer.

That said, zero distances of 50 and 100 m or yd are popular choices for three reasons: 1) they are convenient round numbers; 2) they are far enough to make any inaccuracies noticeable; and 3), they are not so far that external factors (e.g., wind) can significantly affect a bullet’s trajectory during its flight to the target.

If a marksman selects a zero distance beyond 100 m or yd, such as 200 m or yd, they must consider that the bullet travels a significant distance (i.e., multiple cm or in) above the sightline at the apex of its trajectory. If a marksman has a faraway zero distance, and the target is at the halfway point, this is the only situation in which the point-of-aim is actually higher than the center of the reticle. However, this concern is irrelevant if the marksman does not plan to shoot before their zero distance.

9.c Zeroing

The zeroing process involves adjusting the sights so that the point-of-aim of a sight aligns with the point-of-impact of a bullet. Specifically, "zeroing" is a five-step process that is repeated as many times as necessary. (See Image 54, Pg. 83.)

1) Select a zero distance (See Picking a Zero Distance, Pg. 77.) and place there a sturdy target (i.e., one unaffected by the wind). Large, blank sheets of paper work well as they are readily available and inexpensive. The marksman can use a straightedge to draw a large vertical and a horizontal line on the target as a reference. Commercially-sold zeroing-targets are also a very good option.

(Optional step 1.5) If a rifle or ammunition is suspected to be very inaccurate, the marksman begins with a very close target (e.g., 25 m or yd) to ensure that the impacts are at least known to be on the target. This process is called "**getting on paper**," because once the impacts are known to be on a paper target and zeroed a little bit, the marksman can move the target to the actual zero distance to get a precise zero. Good bore-sighting usually makes getting on paper unnecessary up to 100 m or yd with a man-sized meter or yard target. (See Bore-Sighting, Pg. 40.)

2) Shoot a group (See Grouping, Pg. 74.) using the center of the reticle as the point-of-aim. It is important to secure the rifle in place as rigidly as possible, ideally using a rigid support. For example, a shooting benchrest vice is an excellent option for securing. The smaller the groups, the better.

3) Find the center average of the group. (See Image 52, Pg. 76.) If a marksman does not want to walk to the target to examine a group, they can estimate the center average from a distance through the rifle's scope.

4) Determine the angular distance on the target from the center average to the point-of-aim. (See Angular Distance, Pg. 237.) The marksman does not determine the diagonal distance. They instead separately determine the vertical distance for use on the elevation turret, and the horizontal distance for use on the windage turret.

The angular distance can be directly determined through the scope by reading the hashmarks in the reticle if there are any. For example, if the reticle indicates 1 mil left and 2 mils up, the adjustment to the turret would be the same. The marksman must consult the scope manual to determine how many clicks on their turrets correspond to a mil or an MOA on their scope. (See Image 18, Pg. 37.)

However, at the target, a marksman must use a ruler or the target's grid squares to calculate the linear horizontal and vertical distances. But since this step is complicated and involves math, **many marksmen prefer to use trial and error, or buy zeroing targets that come with printed-on instructions.** To convert this linear distance on the target to an angular distance on the reticle, the marksman uses the following:

Variables

- **Linear Distance on Target** *(Linear D on T)* (usually meters or yards) is the distance measured on the target itself.
- **Marksman Distance to Target** *(Marksman D to T)* (usually meters or yards) is the linear distance from the marksman to the target.
- **Mil Distance on Target** *(Mil D on T)* is the angular distance on the target in mils.
- **MOA Distance on Target** *(MOA D on T)* is the angular distance on the target in MOA.
- The *(Linear D on T)* and *(Marksman D to T)* must use the **same units** for the formulas to work (usually meters or yards). This is easy in metric and somewhat more difficult in imperial, as it often requires converting inches into fractional yards or vice versa.
- **3,438 MOA** is a constant from using MOA and does not hold significance.
- **1,000 mils** is a constant from using mils and does not hold significance.

Formula for mils

- *(Mil D on T) = (Linear D on T) x (1,000 mils) ÷ (Marksman D to T)*

Formula for MOA

- *(MOA D on T) = (Linear D on T) x (3,438 MOA) ÷ (Marksman D to T)*

For example, at a target distance of 100 m, one mil is equivalent to 10 cm of distance on a target. So, if a bullet misses the point-of-aim by 10 cm, the marksman must adjust their point-of-aim by one mil. That is:

- *(Mil D on T) = (Linear D on T) x (1,000 mils) ÷ (Marksman D to T)*
- *(Mil D on T) = (Linear D on T) x (1,000 mils) ÷ (100 m)*
- *(Mil D on T) = (0.1 m) x (1,000 mils) ÷ (100 m)*
- *(Mil D on T) = (100 m) x (1 mil) ÷ (100 m)*
- *(Mil D on T) = 1 mil*

Because using this formula for MOA and yards can get complicated, **imperial-system users have a shortcut**, which is to use a zero distance of 100 yd and approximate. That is, there are 3600 inches in 100 yards, and 3600 is pretty close to 3,438, so the MOA formula is simplified:

- *(MOA D on T) = (Linear D on T) x (3,438 MOA) ÷ (Marksman D to T)*
- *(MOA D on T) = (Linear D on T in inches) x (3,438 MOA) ÷ (3600 in)*
- *(MOA D on T) = (Linear D on T in inches) x (~3,600 MOA) ÷ (3600 in)*
- *(MOA D on T) = (Linear D on T in inches)*

Thereby, each inch of distance on the target **at a distance of 100 yd** (or 1/2 in at 50 yd, or 2 in at 200 yd, etc.) is corrected with 1 MOA of adjustment on a scope. This technically overcorrects, but because zeroing is an iterative process, any overcorrection can just be fixed with another iteration of zeroing.

5) Adjust the reticle by the angular distances found in step 4. This involves inputting the vertical angular distance into the elevation turret and the horizontal angular distance into the windage turret. (See Adjusting Elevation and Windage Settings with Turrets, Pg. 36.) Moving the turret marked "up" or "down" on a scope shifts the point-of-impact of the bullet up or down relative to the point-of-aim in the sight picture. It is said, "**The direction is for the bullet**." If the turrets do not have enough rotation to zero the rifle, the scope must be mechanically centered and remounted. (See Getting to Mechanical Center, Pg. 38.)

If done correctly, a marksman can align the center of the reticle to create a zero point at the zero point in one iteration. However, many marksmen over and under-correct and so find that they must repeat the process a few times before finding their zero point.

That being said, all rifle equipment has inherent imprecision (e.g., usually shooting within a .25 mil or 1 MOA area). (See Inherent Imprecision, Pg. 198.) Zeroing is done not when the point-of-aim exactly matches the point-of-impact, but when the two are closer together than the inherent imprecision of the equipment. Inherent imprecision is measured by the smallest grouping diameter that can be achieved by the equipment (See Image 52, Pg. 76.), and this metric is usually advertised by rifle and ammunition manufacturers. Attempting to attain grouping diameters smaller than the equipment itself can attain is a futile exercise, and such a mistake is called "**chasing rounds**," since marksmen constantly make small, erratic adjustments to their point-of-aim, making it seem like they are chasing something.

In some cases, a rifle may have multiple sights, such as a scope and iron sights, or a scope and a red dot. Typically, the primary sight is more precise while the secondary sight is more durable and is used if the primary breaks. Once the first sight is zeroed, the second sight can be "co-witnessed" off the first. Co-witnessing is the act of aligning one sight's point-of-aim to another's without verifying the point-of-aim by firing a bullet. This is fine for hunting or target shooting; however, if the backup sight's accuracy is crucial for the marksman's safety, the second sight must also be properly zeroed independently of other sights. Not co-witnessing is also important when using an infrared laser and a night vision device for shooting in the dark. Such systems differ significantly from scopes, and so co-witnessing can introduce error in the secondary sight.

After zeroing is complete and the reticle is adjusted, marksmen must know **how much more adjustment the reticle still has in all directions**. For example, if an elevation turret allows for a total adjustment range (a.k.a., "travel") of 25 mils, at the mechanical center the reticle can be adjusted 12.5 mils up and down. If the zeroing process required the reticle to be adjusted 10 mils up, then the scope would only have 2.5 additional mils of upward adjustment range. This is important for long-range marksmen because if they are unaware of their remaining range and then need that range, the scope would not be able to physically adjust the reticle enough to aim at a target.

If the turrets do not have enough remaining range for the marksman's purposes, the scope must be mechanically centered and remounted. (See Getting to Mechanical Center, Pg. 38.) Because upwards reticle adjustment is much more useful than downwards adjustment (because bullets mostly fall), some marksmen choose to mount their scopes with an inclined shooting block, known as a riser, to tilt the scope slightly upward and purposefully misbalance the range of the elevation turret. If neither of those solutions gives the marksman enough vertical adjustment range, a marksman must buy a scope with more adjustment range.

The process of zeroing is done in a safe environment and is a good time to learn. A marksman can receive feedback from a helper or instructor observing the process. (See Teaching, Pg. 230.) A marksman can also test their equipment by firing many rounds to attempt to identify subtle issues with their rifle, such as a loose scope or warping stock. This extended familiarization and checkup can be performed each time any rifle component changes, such as the installation of a new scope or a change in ammunition.

Zeroing a Rifle

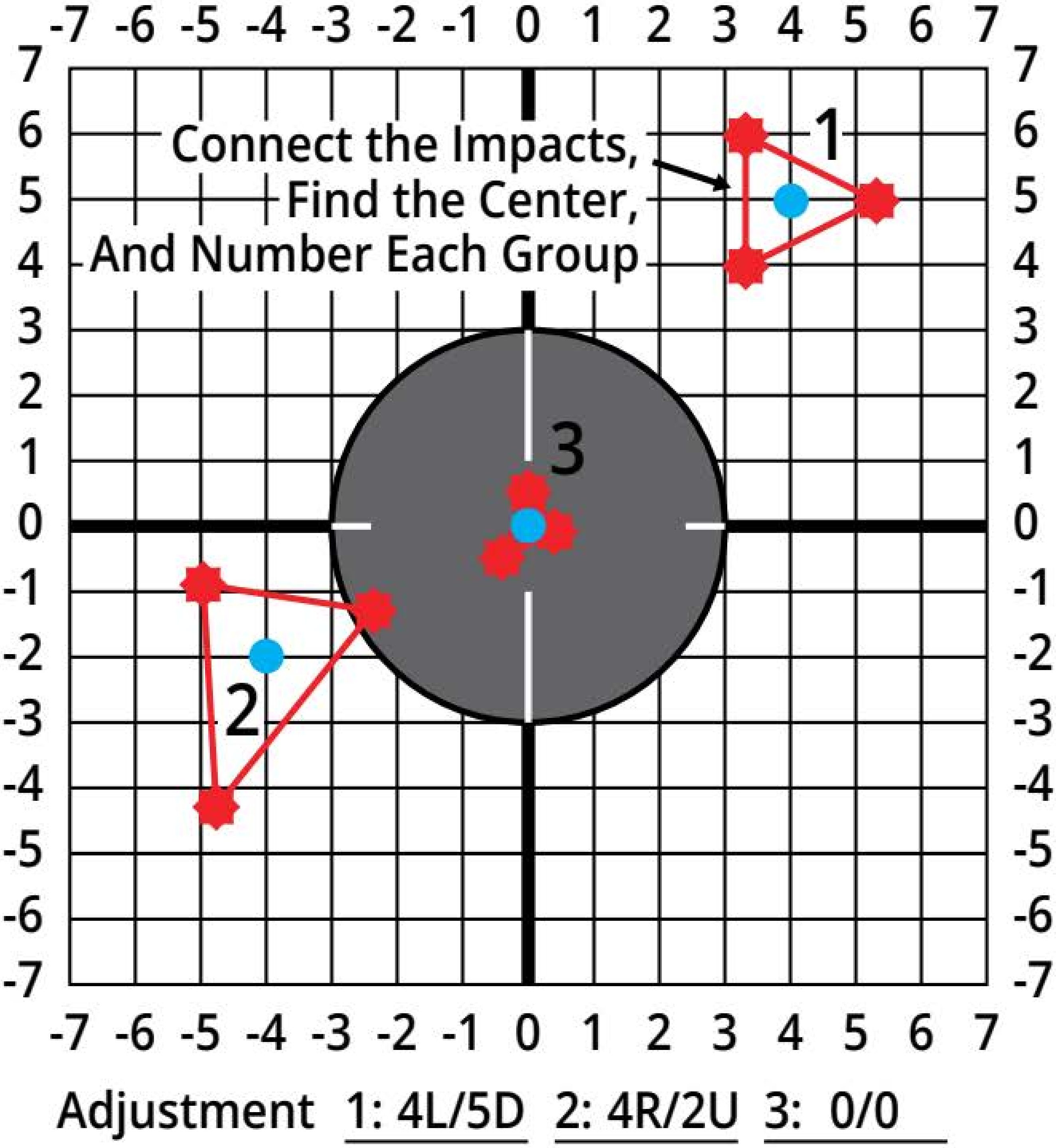

-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7
Connect the Impacts,
Find the Center,
And Number Each Group
1
2
3
Adjustment 1: 4L/5D 2: 4R/2U 3: 0/0

Image 54: This diagram shows the results of the step-by-step process. The first group, labeled "1" was shot too high and too far to the right. After using a marker to draw lines between the impact holes, the marksman determined the center of the group was at the coordinates 4, 5. Therefore, the marksman needed to adjust their scope (or rather the reticle inside the scope) to the left by 4 units (4L) and down by 5 units (5D). Unfortunately in this example, the marksman overdid their corrections (for whatever reasons) and ended up on the other side of the target center. Performing the same steps, the marksman determined that the center was 4 to the left and 2 down from the center. Therefore, they adjusted their point-of-aim 4 to the right (4R) and 2 up (2U). Afterwards, the third group's center was at the center of the target, and the rifle and scope were successfully zeroed.

9.d Resetting Elevation and Windage Turrets to Zero

The elevation and windage turrets on a scope respectively control the vertical and horizontal movement of a reticle inside a scope. When the reticle needs to be moved up or down (i.e., elevation), or left or right (i.e., windage), the marksman turns these turrets. (See Adjusting Elevation and Windage Settings with Turrets, Pg. 36.) However, after being rotated, the numbers on the turrets are set randomly; whereas instead, they must have the number "0" be represent the zero point and zero windage.

Ensuring that the turrets correctly represent the reticle's deviation from its zero is critical. Resetting the numbers on the turrets allows the marksman to be able to get back to their zero setting consistently. (In theory, any digits on the turrets could represent the zero setting, but shooting is stressful and makes marksmen easily forget or confuse basic facts, especially digits.)

So that turrets can be set to zero without changing their internal setting, most modern scopes have removable turret caps on top of the actual adjustment mechanism. The cap is screwed off, usually with an allen wrench (a.k.a. hex key), and rotated so that the number "0" on the turret faces directly backwards. (See Image 55, Pg. 85.) The cap is then screwed back on to set it in place. (It is crucial to avoid over-tightening and potentially stripping screws.) These caps are useful because to zero a rifle a marksman may have to turn the turrets a random amount, and remembering that the zero is at "7" for elevation and "3" for windage can be arduous. It is far easier if the zero is at "0" on both dials.

If a click is heard or felt while rotating the turret, those clicks must be reversed by the equivalent number of clicks in the opposite direction. That is because a click represents an adjustment to the reticle; and therefore, failure to properly reverse the adjustment would require the marksman to re-zero the scope.

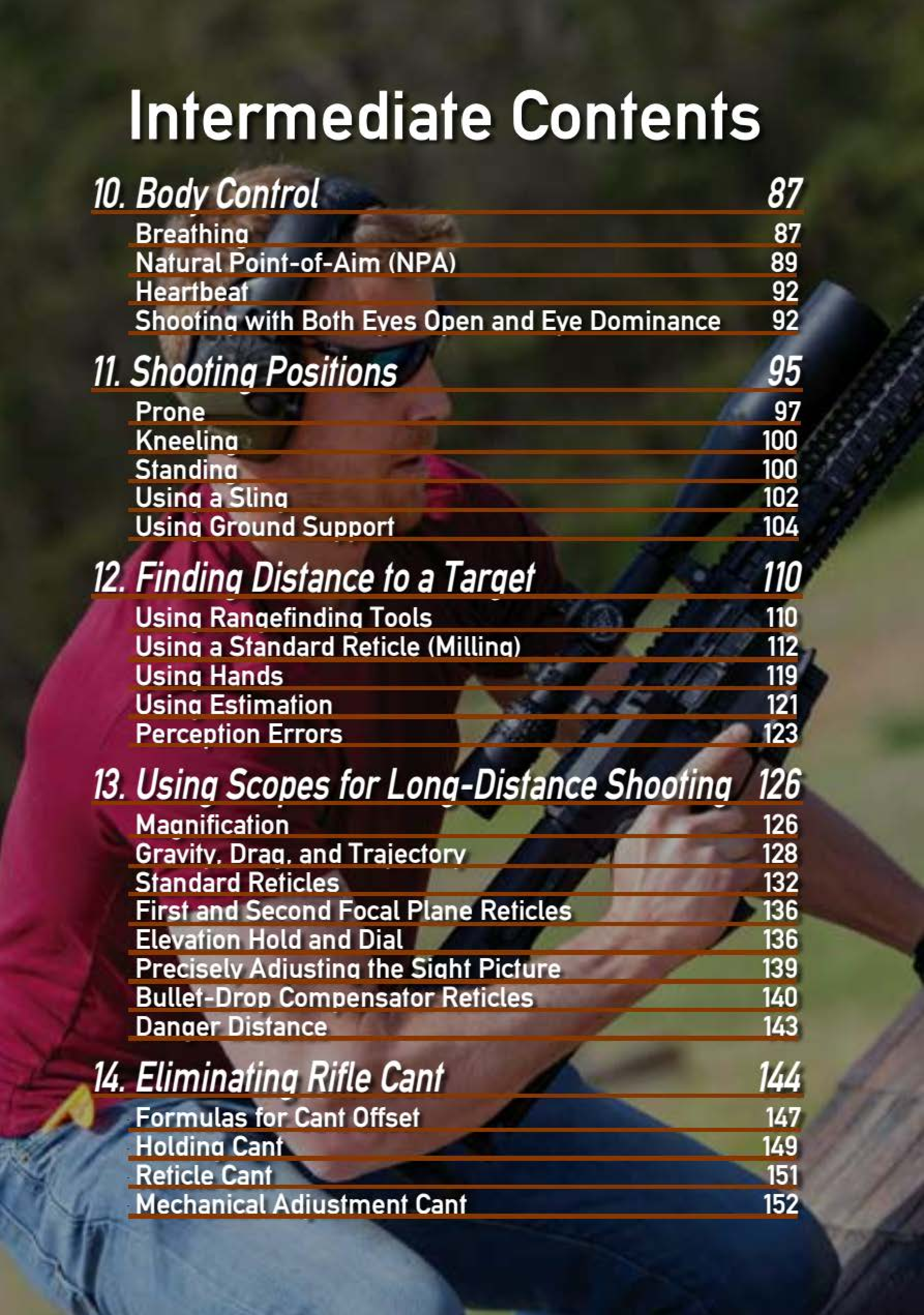
If a scope does not have removable caps, or if the marksman wants an additional marking, they can **draw a line down each turret** onto the scope. Then if a turret were to be rotated, each half of the line would become misaligned. The marksman can reset the scope to zero by rotating the turret until the two halves of the line are connected again.

A third, extreme, method for recording the zero setting is for a marksman to record how far the zero setting is into the entire adjustment range for each

Image 55: A Marine pre-scout sniper course instructor prepares to remove a turret cap on a Leupold TS-30A2 Mark 4 scope by removing its set screws.

turret. For example, a marksman can take a zeroed rifle and determine how many clicks it takes to reach the end of the adjustment range from the zero setting in all four directions. With this information, the marksman can turn a turret all the way to the end of its adjustment range in any direction and then adjust back by the number of clicks they recorded to reach the zero setting. This method is the most time-consuming, but also the most reliable as it relies on the physical limitations of a scope's internal parts.

Some scopes come equipped with a "**zero-stop**" feature on the elevation turret. It prevents the marksman from going into negative numbers on the elevation dial. In other words, it is an artificial wall that blocks off part of an elevation turret's adjustment range. With a zero stop, a marksman doesn't have to look at their elevation dial to reset it to zero; they can just rotate it until it stops rotating. Zero stops are useful because needing elevation above the zero point is very rare. However, if a marksman does want to prepare for that, they can set their rotation stopping feature to a negative number instead of zero. For example, they can set their stop to negative four clicks, and always adjust four clicks backwards after blindly rotating the zero stop to its limit.



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Intermediates (100 to 300 Meters or Yards)

> *The truth is that any good modern rifle is good enough. The determining factor is the man behind the gun.*
>
> *—Theodore Roosevelt, 26th U.S. President and Army Colonel*

At distances under 100 m or yd, hitting a standard-sized target is generally straightforward. Simply aiming and firing are usually all that is required for you to hit the target. Therefore, the art of shooting truly starts when targets are situated 100 m or yd away or beyond because you can no longer solely rely on your intuition to improve.

Most marksmen at this intermediate level are skilled enough to know how to control and position their bodies. They can also find the distance to their target without a rangefinder, fully utilize their scopes, and keep their rifles perfectly vertical without any cant.

10. Body Control

The human body **continues to move** even as a marksman remains as "still" as they possibly can. Many muscle movements are only partially voluntary, such as breathing and blinking, while others are completely out of a person's control, such as the beating of the heart.

These muscle movements translate to the rifle and can slightly move it, making aiming difficult. Therefore, marksmen can shoot more precisely by exerting conscious control over their semi-voluntary body movements to calm them. Additionally, a marksman can increase their situational awareness and comfort if they learn to skillfully control how they look through a scope.

10.a Breathing

Breathing is a simple topic: moving the chest up and down while shooting moves the point-of-aim up and down as well. To stay the point-of-aim, a marksman must suspend their breathing. That is, to maintain a consistent chest height, the marksman must control their exhaling and inhaling. To do this, a marksman **waits for their natural exhale to complete**. Then the marksman does not inhale until they fire their rifle to ensure that their lungs

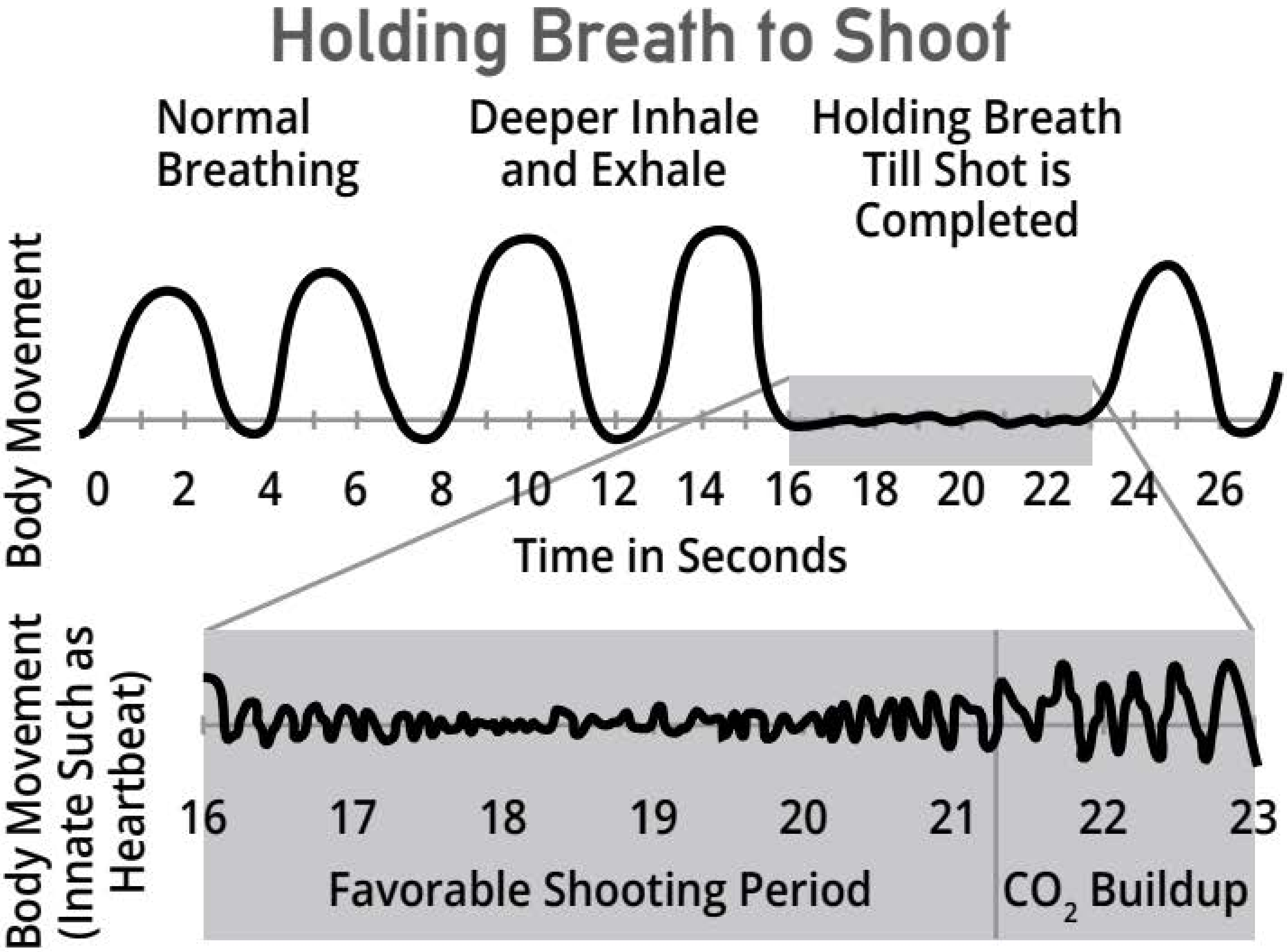


Image 56: Breathing moves a marksman's chest up and down. So to keep their body as still as possible, marksmen hold their breath while shooting. To prepare for this, marksmen prepare with deep inhales. Holding breath for too long creates **carbon dioxide buildup**, which negatively affects precision. This diagram illustrates just one marksman's experience. Some marksmen can effectively hold their breath for longer or shorter periods than other marksmen can.

are not moving (and therefore cannot alter their point-of-aim) while shooting. (See Image 56, Pg. 88.)

Not breathing for a moment before shooting is perfectly fine, but any pause longer than about eight seconds can lead to imperceivable muscle shaking and issues related to carbon dioxide buildup and oxygen deprivation. If eight seconds pass and the marksman has not shot, they simply need to breathe in and out again to reset the process.

The completion of a natural exhalation is the ideal part of the breathing cycle to pause at, since it is the most repeatable. In contrast if a marksman chooses to partially exhale, they may exhale a different amount of air each time they aim their rifle, meaning their chest would be at different heights and their points-of-aim would therefore become inconsistent. That being said, it is important for the exhale to be natural, and not a complete emptying of the lungs. The goal is repeatability, and an unnatural exhale is neither repeatable nor comfortable.

A useful acronym for breathing control is **BRASS**:

Breathe – The marksman takes a deep breath and aligns their sights during the natural exhale. They continue to refine their point-of-aim during subsequent natural exhales.

Relax – While maintaining a calm and regular breathing pattern, the marksman actively tries to relax their muscles and mind.

Aim – The marksman finalizes their point-of-aim.

Slack – The marksman pulls the trigger to the point just before it fires (this is called "removing slack.").

Squeeze– They then squeeze the trigger when they have both reached the next natural exhale and confirmed that their point-of-aim is still accurate. The trigger is calmly pulled and never jerked.

All that being said, the ability or need to control one's breathing is often over-exaggerated because the concept of timing one's breathing cycle is easier to explain than many other concepts. In reality, the movement of the chest during breathing is relatively small and uninfluential. Moreover, in military and hunting scenarios, marksmen sometimes are not able to wait to enter the perfect breathing pattern before taking the shot but must shoot anyway before the target moves. In fact, military marksmen regularly participate in "stress-shoots," where they practice marksmanship after intense exercise to learn to remain accurate and precise in high-stress situations during which their breathing is not fully controllable.

10.b Natural Point-of-Aim (NPA)

The natural point-of-aim (NPA) refers to the location that a held rifle points when the marksman's body is relaxed. Therefore, shooting with an NPA is almost synonymous with shooting while as relaxed as possible (i.e., a marksman must feel so relaxed that they could almost fall asleep).

There are two reasons why a marksman would want to shoot from a relaxed position with an NPA. First, **it is far easier for a marksman to consistently use a single shooting position**; full relaxation is a single, known state. In contrast, a marksman can be partially relaxed in any number of ways and body configurations. This is the same reason that marksmen shoot at their full, natural exhale, instead of only partially emptying their lungs.

This repeatability also allows a marksman to take more shots in faster succession at a target because it is easier to fully relax than to partially relax any particular part of their body. This is important because recoil always relaxes the body anyway, so if a marksman is already fully relaxed then recoil cannot relax the marksman's body significantly more.

The second reason for using an NPA is to reduce muscular tremors, which are caused by muscles attempting to maintain a fixed position. These tremors can transfer to a marksman's rifle, causing both the sight picture and point-of-aim to waver. Shooting from a relaxed position minimizes this instability.

That is not to say that all wavering can be completely eliminated. That is simply not humanly possible. A common mistake made among new marksmen is trying to overly perfect each shot they take. Instead, a marksman must act smoothly and fire when the crosshairs have sufficient, not perfect, stability.

To further relax their muscles, many marksmen employ stability tools such as slings and supports. (See Using a Sling, Pg. 102.) (See Using Ground Support, Pg. 104.) For example, by employing a proper kneeling position and a loop sling, a marksman can minimize errors to less than 1 mil (or 4 MOA) for extended periods.

The ideal shooting position is **just relaxed enough** so that a marksman can aim their rifle from that position without any additional force. That is, a marksman must control their body in such a way that it interferes the least possible amount with shooting. This is achieved by being slow and calculated with each movement and shot.

To determine an NPA, a marksman can assume any shooting position and close their eyes. Once comfortable in that position, they must focus on completely relaxing their body and take a few deep breaths. This breathing work and subsequent relaxation allow the rifle to settle and naturally shift into its NPA. The marksman can then open their eyes. Wherever the rifle points at that time would be the marksman's NPA in that specific shooting position. (It is normal for the NPA to be off-target at that point; it is rare for a marksman to close their eyes and be able to maintain their target.) An alternative method to finding an NPA is to fire the rifle to force a relaxation. Wherever the rifle settles after recoil is its NPA.

Every shooting position for every marksman has its own NPA. However, it is important to note that the NPA of a shooting position may not necessarily be aligned with the marksman's target. Therefore, **expert marksmen can predict which positions can lead to an NPA that is aligned to the target** before even getting into position, which helps them avoid readjusting their aim and rifle. To develop this predictive skill, marksmen must consistently use the same shooting positions, so that they can associate each position with its corresponding NPA.

Adjusting the Natural Point-of-Aim

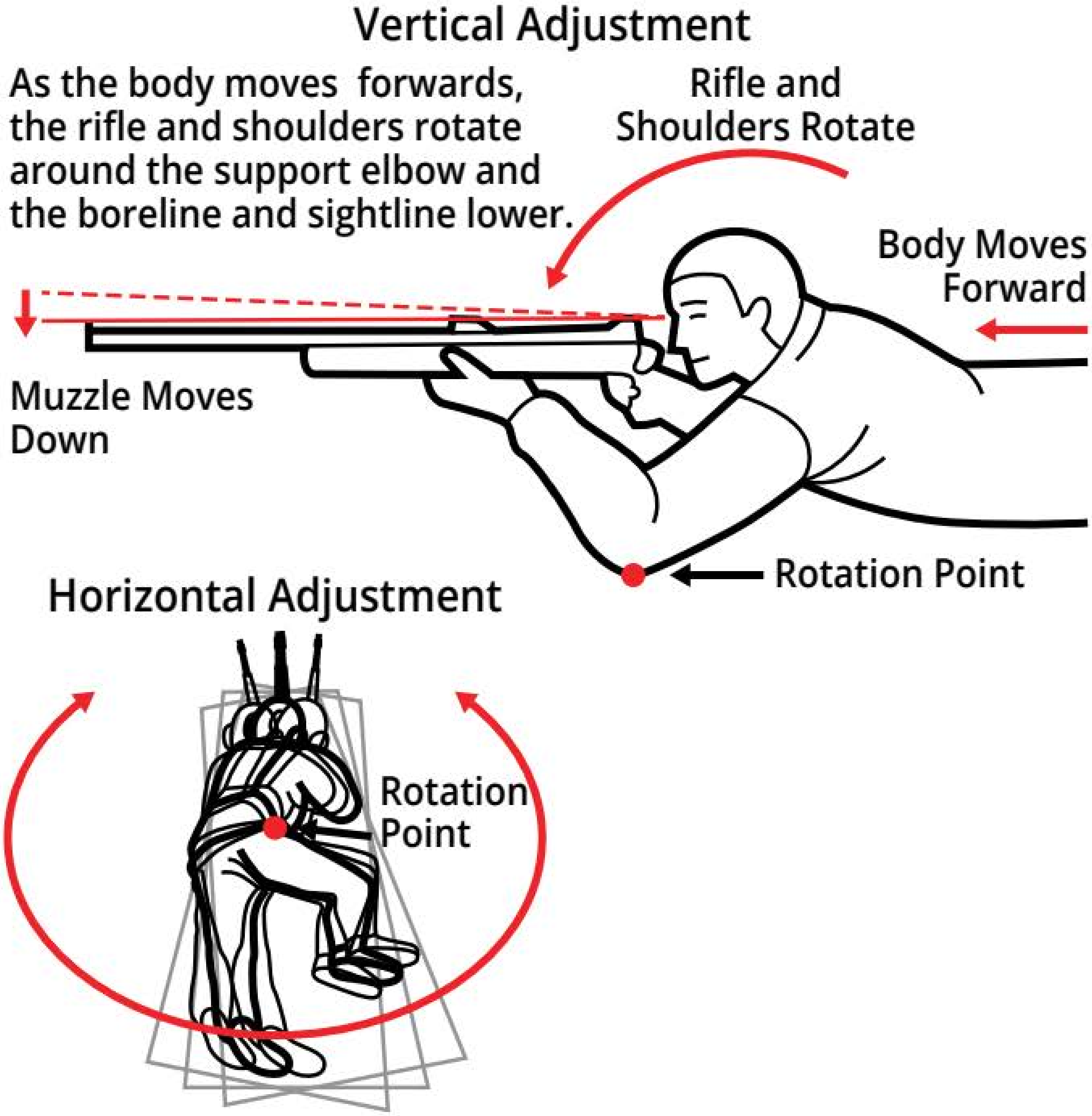

Vertical Adjustment
As the body moves forwards, the rifle and shoulders rotate around the support elbow and the boreline and sightline lower.
Rifle and Shoulders Rotate
Body Moves Forward
Muzzle Moves Down
Rotation Point
Horizontal Adjustment
Rotation Point

Image 57: Because the natural point-of-aim is present when the body is in a relaxed position, to grossly adjust the point-of-aim, the body needs to move to an entirely new position. This is done **through rotation**. Adjusting the point-of-aim up or down is done by moving the lower body forward or backward to rotate the upper body about the support elbow. Adjusting horizontally requires the marksman to rotate left or right about their hips.

Having said that, even the most advanced marksmen still need to make adjustments to their shooting position once they are in it. These adjustments align the NPA with the target, and can be either gross or minor.

Gross adjustments to the NPA require pivoting the entire body and any supports used. In most cases, these bodily adjustments are made using the lower body. In the prone position, for instance, a marksman would use their legs to rotate around their supporting elbow. In the kneeling position, the entire body would pivot on the forward foot. Lastly, in a standing position, the marksman would rotate around their support.

Minor adjustments, on the other hand, involve adjusting one's limbs independently. For example, in the prone position, the NPA can be adjusted horizontally by slightly moving the support elbow to the left or right. And the NPA can be adjusted vertically by nudging the elbow on the side of the trigger, which raises or lowers the shoulder and consequently the muzzle of the rifle. Other minor adjustments include: moving the support hand forward or backward on the handguards; positioning the stock higher or lower on the shoulder; or finding a stable footing by digging toes into the ground and either pulling their body forward or pushing it back.

10.c Heartbeat

The heart pumps blood with pressure waves (i.e., beats), and not in a consistent flow. A beat of the heart may have enough force to transfer through a marksman and into the rifle, shifting the point-of-aim. Therefore, many depictions of snipers show them timing their shooting to a specific, consistent step in the beating process, just like skilled marksmen time their shots to their breathing. (See Breathing, Pg. 87.)

However, any such depictions are inaccurate because skilled marksmen do not time their shots to their heartbeat and disregard their pumping cycle entirely. Simply put, the heartbeat is relatively unimportant compared to other priorities during shooting, such as breathing and keeping the target in the crosshairs. Timing a heartbeat would also be more difficult than timing a breathe because, unlike breathing which can be consciously paused, the pumping cycle is very short and cannot be paused.

That is not to say that the heartbeat is irrelevant to shooting. If a marksman claims to see the reticle "beat" alongside their heartbeat, they may be gripping the rifle too tightly. Alternatively, they could be so overly excited that their blood is being pumped more strongly than normal. Either way, the best and only way to control a strong, fast heartbeat is to calm down. If a marksman's heart is racing, they can **engage in breathing exercises to become more physically calm**. Specifically, a forceful exhale not only ensures a consistent chest height, but also aids in relaxation and naturally slows down a rapidly beating heart.

10.d Shooting with Both Eyes Open and Eye Dominance

Almost all long-range rifles are designed to have the marksman's right eye look through the scope. Most marksmen, therefore, close their left eye to

Eye Dominance Testing

Image 58: A Marine checks for his dominant eye using the Miles Test. Joint Base Andrews, MD, 03 May 2013

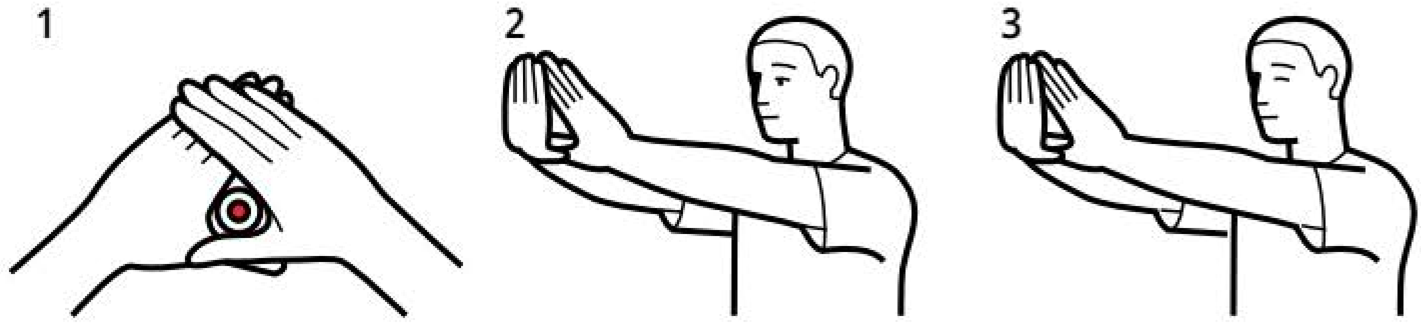


Image 59: The **Miles Test**: Step 1 - Make a triangle with your hands, centering an object. Step 2 - Fully extend the arms. Step 3 - With both eyes open, look through the triangle to the object. Close the left eye. If the object remains in view, you are right-eye dominant, and if the object disappears you are left-eye dominant.

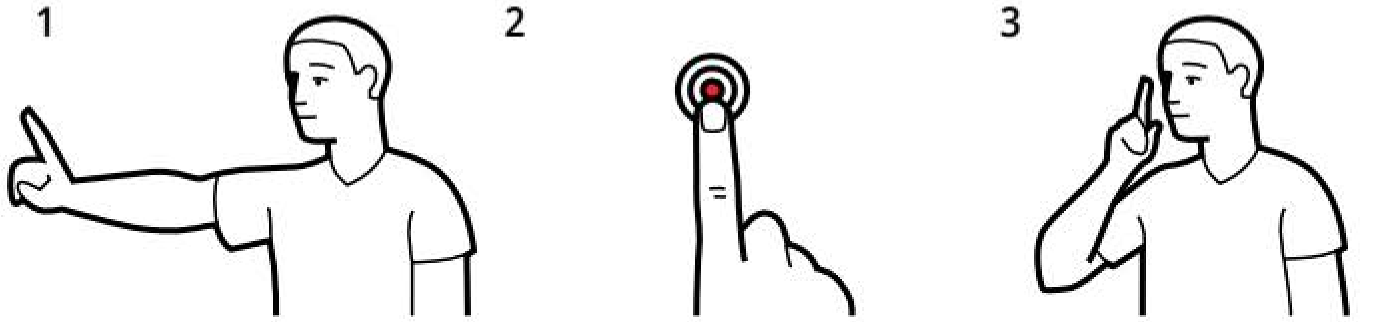


Image 60: The **Porta Test**: Step 1 - Fully extend the arm, and point at an object. Step 2 - Keeping the finger in place, alternate closing each eye. Step 3 - Keeping both eyes open, move the finger towards the face while keeping the finger on the object. The eye which the hand moves towards is the dominant eye.

Shooting with Both Eyes Open

Image 61: An infantryman with a Scout Sniper Platoon, in the 31st Marine Expeditionary Unit shoots targets with **both eyes open** using an M110 Sniper System during a static live fire range. Camp Hansen, Okinawa, Japan, 08 Jul 2020.

Image 62: The Peruvian marksman on the left favors the right side of his body, while the marksman on the right favors the left side of his body. Both marksmen keep both of their eyes open to observe their surroundings. Cerro Tigre, Panama, 15 May 2024.

increase the brain's focus on the sight picture that is seen by the right eye. And that is a good technique to avoid fatigue if the marksman fires quickly and they can be unaware of their surroundings (e.g., when target shooting). However, many marksmen must maintain awareness of their surroundings at all times (e.g., military marksmen) and so cannot afford to close one of their eyes. These marksmen must learn to shoot with both eyes open.

The process of learning to shoot with both eyes open begins with determining which of the marksman's eyes is dominant. The majority of people have a brain that naturally favors the input from one eye over the other, just as the vast majority of people favor one hand over the other (although being ambi-eyed is far more common than being ambidextrous). The image from the scope is always more important than the surroundings, so **marksmen with both eyes open always shoot better when they look through the scope with their dominant eye**.

To determine eye dominance, there are a couple of tests available. The Miles Test (See Image 59, Pg. 93.) and the Porta Test (See Image 60, Pg. 93.) are both good options. It is not uncommon, however, to have equal dominance in both the left and right eyes; therefore, any eye-dominance test has a risk of generating a false positive.

It is crucial to understand that the dominant eye does not necessarily have clearer vision. Instead, it is the brain that prioritizes visual information from one eye. Notably, some individuals may have variable eye dominance, where the brain prioritizes one eye over the other based on external factors such as brightness or distance.

Cross-dominant marksmen, who are right-handed and left-eye-dominant or vice versa, must make a choice regarding which side to shoot from. While shooting with the dominant eye always makes processing the sight picture easier, most cross-dominant marksmen opt to use standard rifles designed for right-sided shooting. They therefore sacrifice better focusing on the sight picture for an easier experience using their equipment.

Learning to shoot with both eyes open involves training oneself to instinctively **ignore, rather than eliminate**, the visual input from the non-dominant eye. This is not intuitive at all, and a marksman must master shooting with only one eye open before advancing to two eyes open. At the beginning of practicing drills with both eyes open, seeing double or experiencing blurry vision may be a common issue. However, this diminishes with time and practice.

One drill that can help train the eyes and brain to favor one eye when both are open involves holding a pen upright at arm's length. With the non-preferred eye closed, aim the pen's tip at an object located at least 1 m or yd away. Then, without moving any part of the body, open and close the non-favored eye. The goal is to maintain the sight picture of the favored eye. This exercise allows marksmen to recognize the appropriate visual input for the favored eye when shooting with both eyes open. This drill is essentially doing the Porta test repeatedly while attempting to force a result for either the right or the left eye.

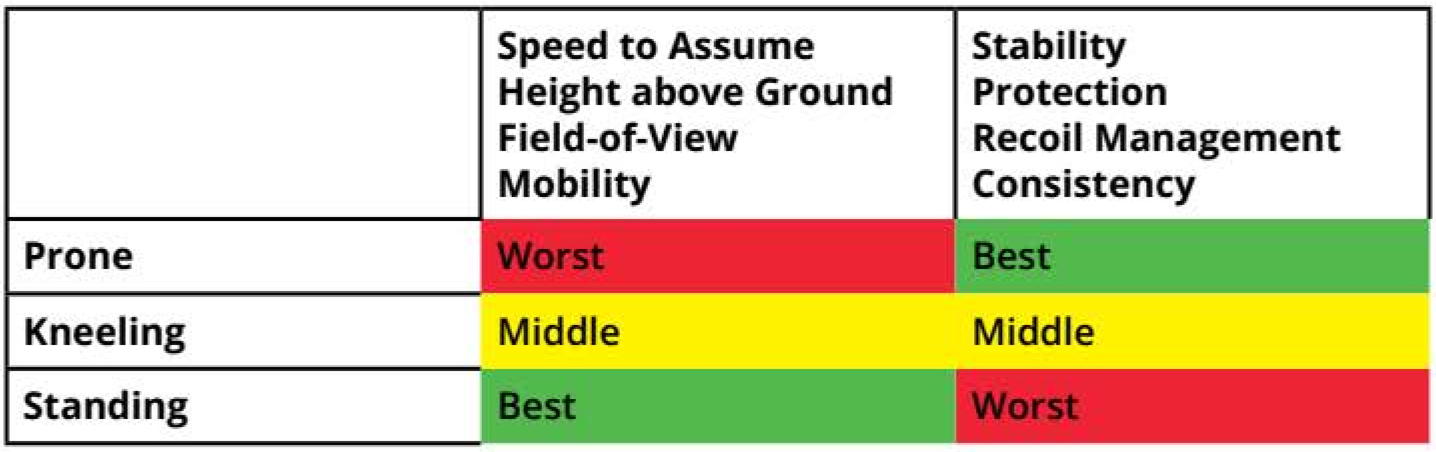
11. Shooting Positions

A shooting position is the set position that a marksman places their body into to fire a rifle. It is distinct from body control because while body control is ongoing, a marksman only enters their position once before shooting and only needs to change their position if they want to grossly alter their point-of-aim.

Shooting positions must optimize for four qualities: recoil management, consistency, visibility, and stability. Differences between shooting positions mostly entail how marksmen position their lower body, as the upper body is mostly preoccupied with holding the rifle. (See Holding a Rifle, Pg. 42.)

Recoil management is the ability of the marksman to return to their point-of-aim after they have fired a rifle. The ability to hold a rifle is described in an earlier section. (See Holding a Rifle, Pg. 42.) However, even if the force of shooting is properly transfered to the marksman's body, the marksman must be able to transfer that force to the ground, or else they

Comparison of Shooting Positions



	Speed to Assume Height above Ground Field-of-View Mobility	Stability Protection Recoil Management Consistency
Prone	Worst	Best
Kneeling	Middle	Middle
Standing	Best	Worst

Image 63: There are different strengths and weaknesses to different shooting positions. Often, the best position is dictated by one's surroundings.

might fall over. This holds particularly true for large-bore centerfire rifles designed to shoot powerful military and hunting calibers. To prepare for the recoil impulse, a marksman always orients their body in a way that allows for the maximum recoil absorption in a straight line. That is, a marksman properly directs the recoil force from the shoulder pocket backwards to the lower back, backwards to the hips, backwards to the feet, into the ground. The marksman also places the majority of their body weight forward of their center-of-gravity. This is already done when in the prone position (i.e., lying on one's stomach); however, when kneeling or standing, a marksman must lean forward slightly.

Consistency is the ability of the marksman to position their body in the same way every time they shoot. A consistent shooting position is crucial because it minimizes any deviations and variables that a marksman has to account for. That is, if a marksman can enter a great position automatically, they have more time and ability to consider other optimizations. Such consistency is gained through lots of practice, which creates muscle memory. With muscle memory, a marksman can perform complex actions automatically and precisely without any conscious effort.

Consistency with oneself is far more important than conforming to someone else's standards. The sports world is full of highly successful athletes who used unorthodox methods, but had simply practiced those methods so much that their expertise in that method allowed them to win. Moreover, everyone's body is different and has different proportions, so overly specific prescriptions would only apply to the "average" person anyway.

Rifle height above the ground is good in that it allows a marksman greater **visibility** above obstacles that may be present between the marksman and their target. However, it can also be dangerous because height allows a marksman to be better seen. Additionally, the lower the rifle is, the more stably a marksman can hold it. **Stability** is always good because it allows the marksman to have a more consistent natural point-of-aim (See Natural Point-of-Aim (NPA), Pg. 89.) and better recoil management.

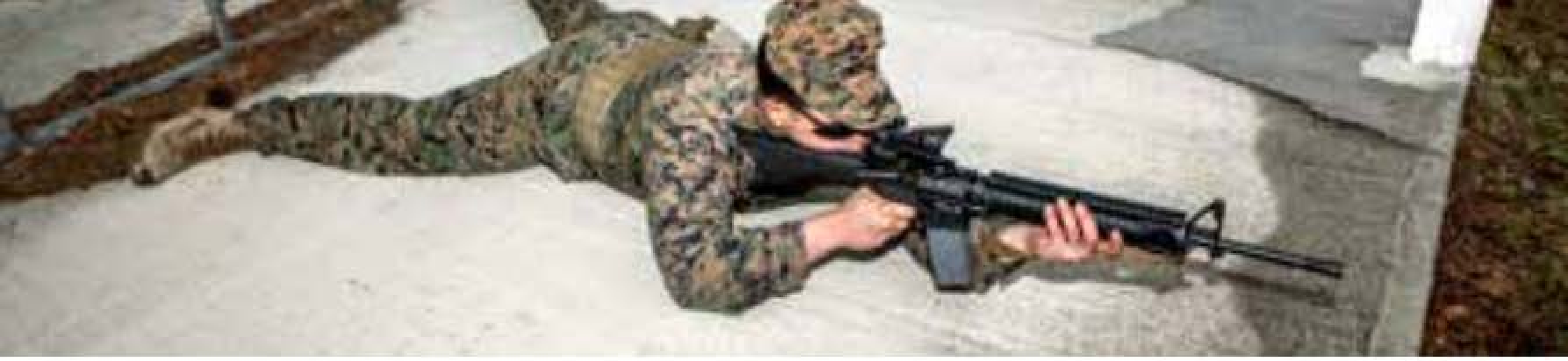
Given all of the above, a marksman can contort their body in infinite ways while holding a rifle. And in fact, if a marksman is faced with imminent danger, they may have to assume uncomfortable, suboptimal positions to properly utilize their surroundings. That being said, there are three basic shooting positions from which all other positions can be derived: prone (i.e., on one's stomach), kneeling, and standing. All three positions have tradeoffs; for example, prone is the lowest and most stable, and standing is the highest and least stable, with kneeling in the middle. (See Image 63, Pg. 96.) (Benchrest "position" was not included here, as marksmen in this position simply sit down without having to orient their legs in any particular way.)

Before diving into the bulk of the text on shooting positions, it is important to note that an effective shooting position relies on **bone-to-muscle** support rather than bone-to-bone or muscle-to-muscle support. For example, placing the triceps on the knee (muscle-to-bone) is superior to resting the elbow on the knee (bone-to-bone). This is because two bones in contact slip off of each other, and two relaxed muscles in contact are not rigid enough to stay in consistent contact for extended periods. Therefore, the most rigid, stable connection is muscle-to-bone.

Of course, due to the limitation of the human body, using artificial supports greatly helps accuracy and precision. All positions can also be subdivided into "unsupported" and "supported." An unsupported position relies solely on the marksman to hold and support the rifle, while a supported position involves using techniques similar to those in unsupported positions but incorporates additional tools such as bags and sticks under the rifle to support and stabilize it better. (See Using Ground Support, Pg. 104.)

11.a Prone

The prone position is the most stable unsupported position because it minimizes the number of joints between the rifle and the ground (i.e., the force of recoil goes into the wrist joint, into the elbow joint, and then into the ground). **It is commonly used when maximum precision is required**, such as when zeroing a rifle. However, it is also the least mobile shooting position, requiring more time and effort to both assume and exit out of it. Additionally, objects such as tall grasses or small walls can obstruct the marksman's



Prone

Image 64: A Marine rifleman with Hotel Company, Weapons Training Battalion demonstrates a proper straight-leg **prone** firing position. This marksman is **maximizing contact with the ground**. Camp Lejeune, NC, 10 Feb 2015.

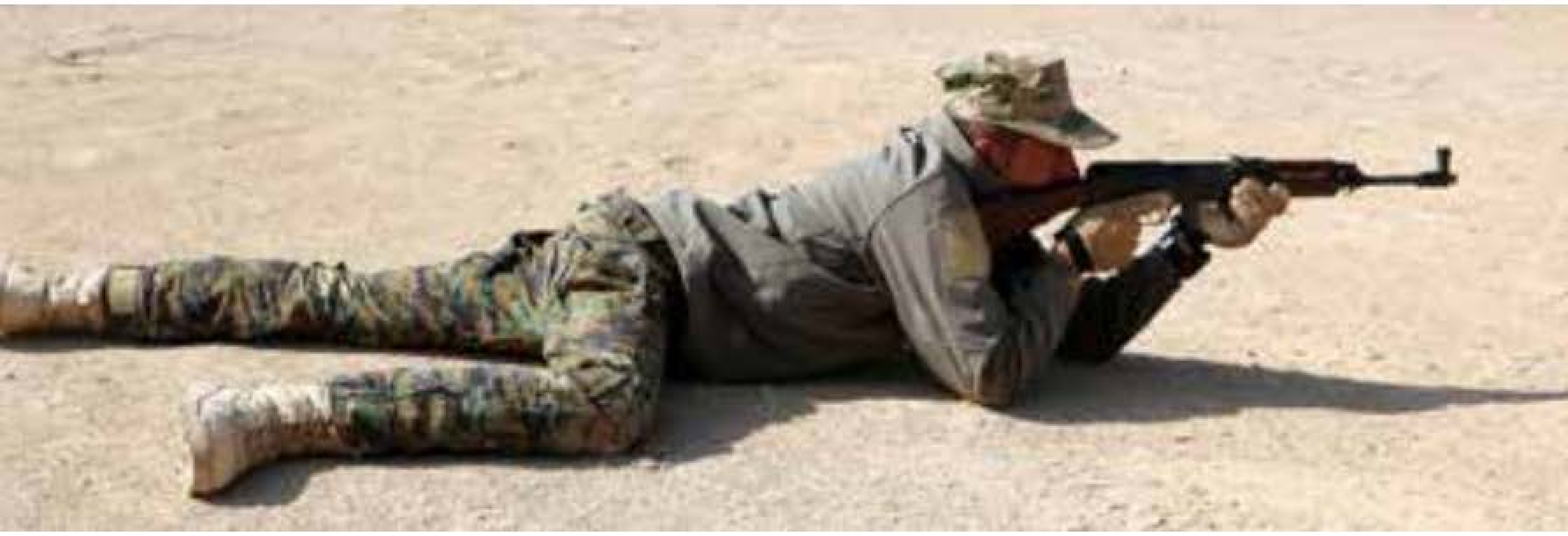


Image 65: An Iraqi soldier lays in the **prone** unsupported position. Al Taqaddum, Iraq, 07 Feb 2018. This marksman is **more comfortable** because lifting a leg allows the head to point forward without bending the neck as far back.

sightline. As a result, the prone position is not commonly used outside of controlled environments such as zeroing a rifle, shooting in a tournament, or a prepared sniper site.

To assume any prone position, a marksman first lies stomach down on the ground. In the **traditional prone position**, marksmen have their legs straight and spread wide apart. Many marksmen then dig their toes into the ground; however, the most flexible marksmen opt to turn their toes outward to touch the ground with their heels, using the inside of their feet and knees to create more contact with the ground. (See Image 64, Pg. 98.)

Marksmen who find it difficult to comfortably arch their back in the traditional prone position for extended periods can use a variation called the **frog-leg** or **sling prone position**. This alternative position requires less flexibility and strength, allowing shooters to maintain stability and accuracy without straining their backs. In the frog-leg prone variation, the marksman bends and raises their shooting-side knee. (See Image 65, Pg. 98.) Bending the knee requires less flexibility and raises the stomach off the ground, making breathing easier. Moreover, the frog-leg knee position allows for better utilization of a sling. (See Using a Sling, Pg. 102.) However, slings are less necessary in the prone position due to the availability of bipods and other supports such as backpacks and rocks.

In the prone position, the upper body must have both elbows on the ground for support. It is important to adjust the elbow spread according to the marksman's body proportions, as having the elbows too close together can cause a rifle to shift left or right, and too far apart can lower the rifle too far down. Additionally, small adjustments to the distance between the elbows are used to adjust the rifle up or down and thereby its point-of-aim.

Moving on to the support arm, the support bicep pushes the rifle into the marksman's shoulder to more effectively manage recoil. The rifle is held in such a way that the marksman's body is **positioned directly behind the gun**, not off to the side. That is, there is a straight line through the barrel, through the marksman's back, through their firing-side hip, ending in their feet. Some marksmen prefer to align the rifle more inward, with the barrel pointing backwards towards their belly button. Either way, ensuring that the barrel points parallel or into the spine and legs ensures that the force of recoil is evenly dispersed throughout their body, reducing the felt impact and allowing for faster follow-on shooting.

The support hand's main role here is to prevent the rifle from rotating and developing a cant. (See Eliminating Rifle Cant, Pg. 144.) Also, moving the support hand and support elbow allows for minor adjustments to the point-of-aim. Moving the support hand up and down the stock adjusts the point-of-aim down and up respectively, while moving the elbow left and right moves the point-of-aim left and right.

If there is a support attached to the fore-stock, such as a front sling swivel attachment point or bipod legs, a marksman can grab it and make a fist under the fore-stock. Placing that vertical fist on the ground with the fore-stock on top is called a Hawkins position. Since fists are not very tall, this position often requires additional support beneath the fist.

If a marksman would prefer not to use their support hand as a monopod, they could alternatively rest their rifle on its magazine (if it has one). However, **using the magazine as a monopod can be unstable or cause jamming** (failure to feed issues) due to putting pressure on and moving the magazine into an unintended position in the magazine well. It is crucial to test each magazine with the firearm during training to ensure its compatibility and effectiveness as a standalone rifle support.

11.b Kneeling

Kneeling serves as a midpoint between the lower and more stable prone position, and the higher and more mobile standing position. (See Standing, Pg. 100.) With three points-of-contact with the ground (i.e., two feet and one knee), **kneeling is ideal for quick shots** where some minor stability is sufficient or when brush, grass, or other vegetation would otherwise obstruct the marksman's sightline in a lower position.

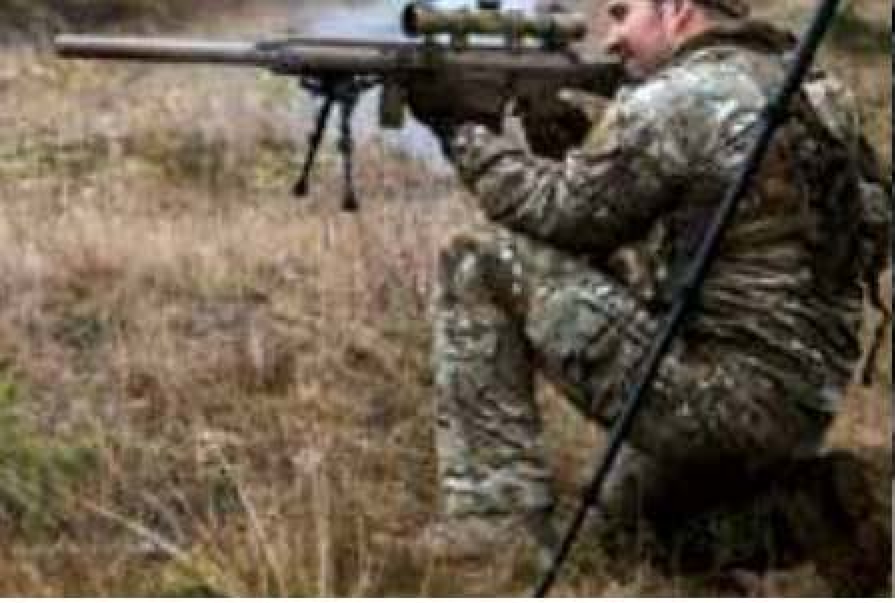
The proper, unsupported kneeling position of a right-handed marksman involves planting their left foot firmly on the ground with their left leg bent at the knee at an approximate 90° angle. The top of the left foot is bent inward to increase side-to-side stability. The marksman then sits on their right foot with the right side of their buttock, with their right knee on the ground. (See Image 68, Pg. 101.) In combat situations where shooting around the sides of cover is necessary, marksmen must keep their right knee much closer to their left knee to keep it behind whatever cover the marksman is using.

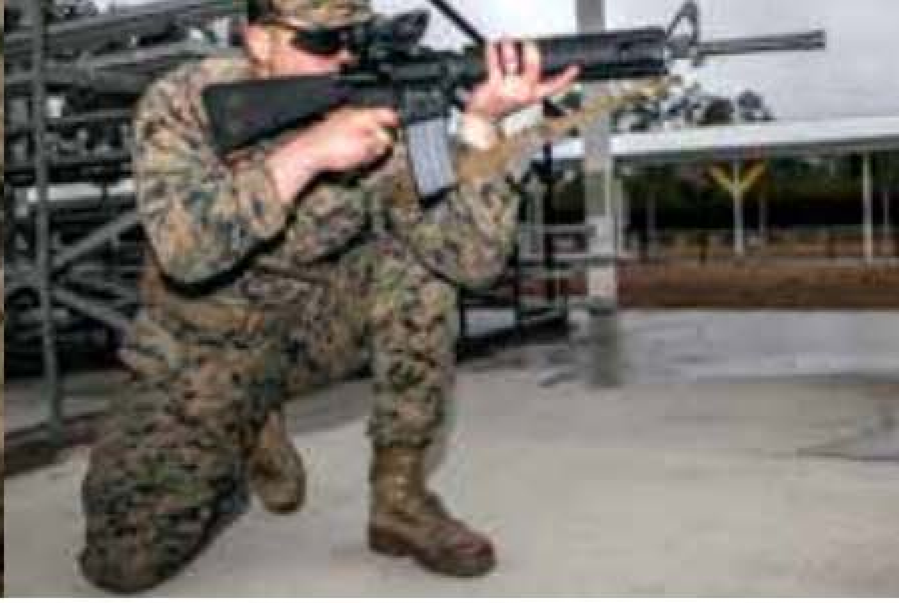
Once in the kneeling position, the marksman's torso must be comfortably erect and relaxed, avoiding a slouched posture, with their body rotated 30 to 45 degrees towards the rifle. The marksman then rests their left triceps (muscle) on their knee (bone) by positioning the elbow (bone) just before (See Image 66, Pg. 101.), or just before (See Image 67, Pg. 101.), the knee, avoiding bone-to-bone contact and thereby any potential slipping. The support arm is directly under the rifle when the marksman looks down. If the arm is not properly aligned, the marksman may be overexerting their bicep muscles and not using their natural point-of-aim. (See Natural Point-of-Aim (NPA), Pg. 89.) (That is, overuse of supporting muscles can lead to muscle fatigue and trembling over time. This, in turn could potentially lead to wobbling of the barrel and thereby decrease the accuracy of the shot.)

Once the marksman has established a comfortable kneeling position and their natural point of aim, they can adjust the scope's vertical sight picture by moving their forward foot closer to or farther from their body. This allows for precise alignment without compromising stability.

11.c Standing

The standing position (a.k.a., offhand position) **offers the marksman the best view of their surroundings** since the eyes and the rifle are higher than in any other position. However, standing is also very unstable. There are only two points of contact with the ground, the feet, and there are also many joints

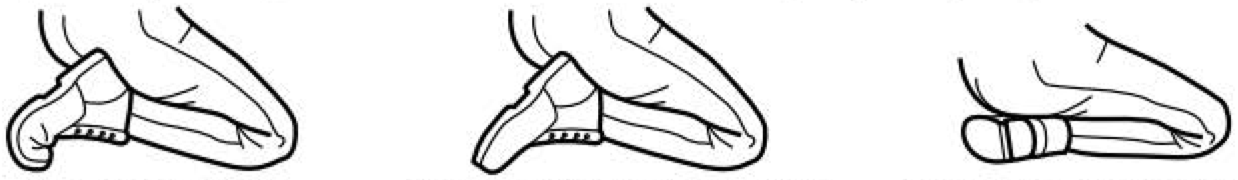




Kneeling

Image 66: A Soldier fires from a hasty **kneeling** position. This marksman places his **elbow behind his knee**. Camp Adazi, Latvia, 16 Nov 2021.

Image 67: A Marine kneels with a sling. (See Using a Sling, Pg. 102.) He places his **elbow in front of his knee**. Camp Lejeune, NC, 10 Feb 2015.



Toes Flexed Up

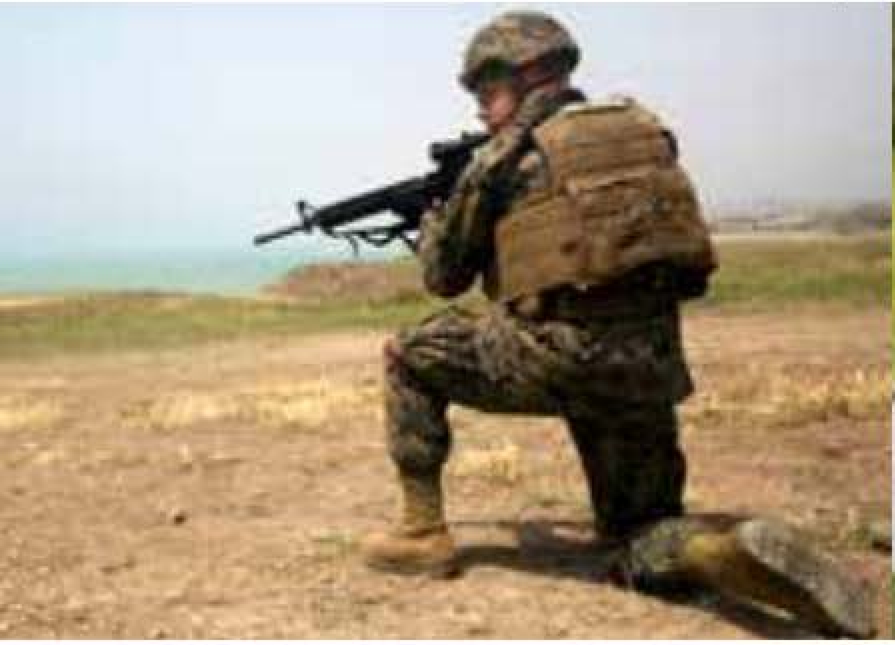
Front of Toes on Ground

Side of Foot on Ground

Ankle Supported by a Shooting Bag

Top of Foot on Ground

Image 68: A lower rear foot is more stable, but slower to rise from and less comfortable. Inflexible marksmen may not even be able to enter a low position.



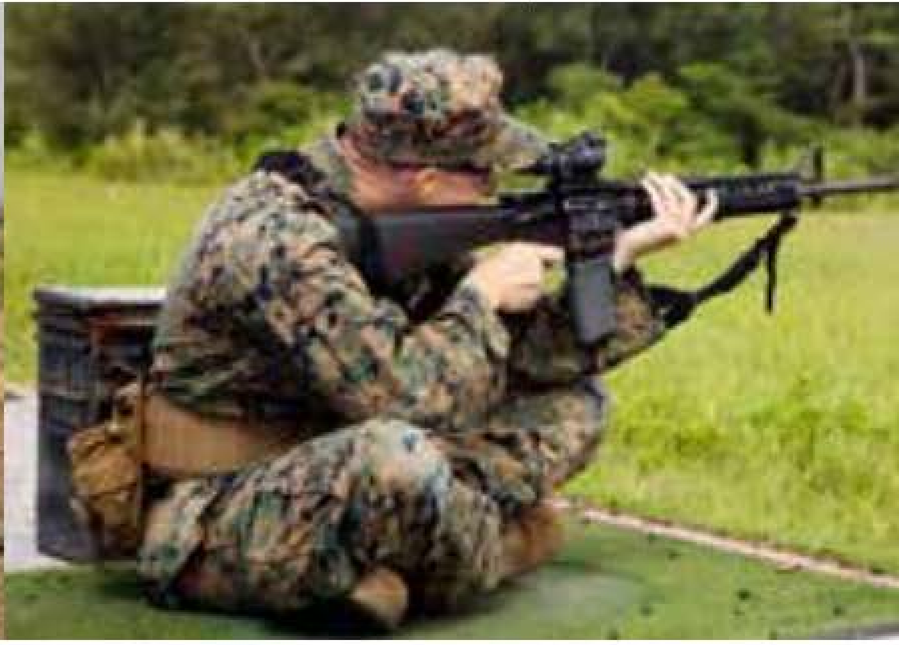


Image 69: A U.S. Marine **kneels** with his back leg vertical and his rear toes pointing outwards. This shooting position is **marginally higher but less stable** than a standard position. Drasi, Italy, 02 May 2018.

Image 70: A U.S. Marine **sits** cross-legged and digs his elbows into his legs. This shooting position is **marginally lower but more stable** than a standard position. Camp Hansen, Okinawa, Japan, 09 Jul 2018.

between the rifle and the ground that are prone to shifting (i.e., the vertebrae, the hips, the knees, the ankles, etc.). Therefore, standing is not viable beyond 300 m or yd.

A marksman can maximize their stability first by placing their feet shoulder-width apart, with the trigger-side foot slightly behind the support-side foot. The marksman's body must be relatively rigid to minimize shaking. Part of that rigidity comes from keeping the knees mostly straight, but not necessarily locked. (See Image 71, Pg. 103.)

In this position, the marksman shifts their weight so that most of their weight is on their front foot. This is done to prepare for recoil pushing them back. A slight lean forward into the buttstock can be helpful. (See Image 72, Pg. 103.) Then, the support hand grasps the rifle at the midway point of the fore-stock. If possible, a marksman braces their elbows against their ribs.

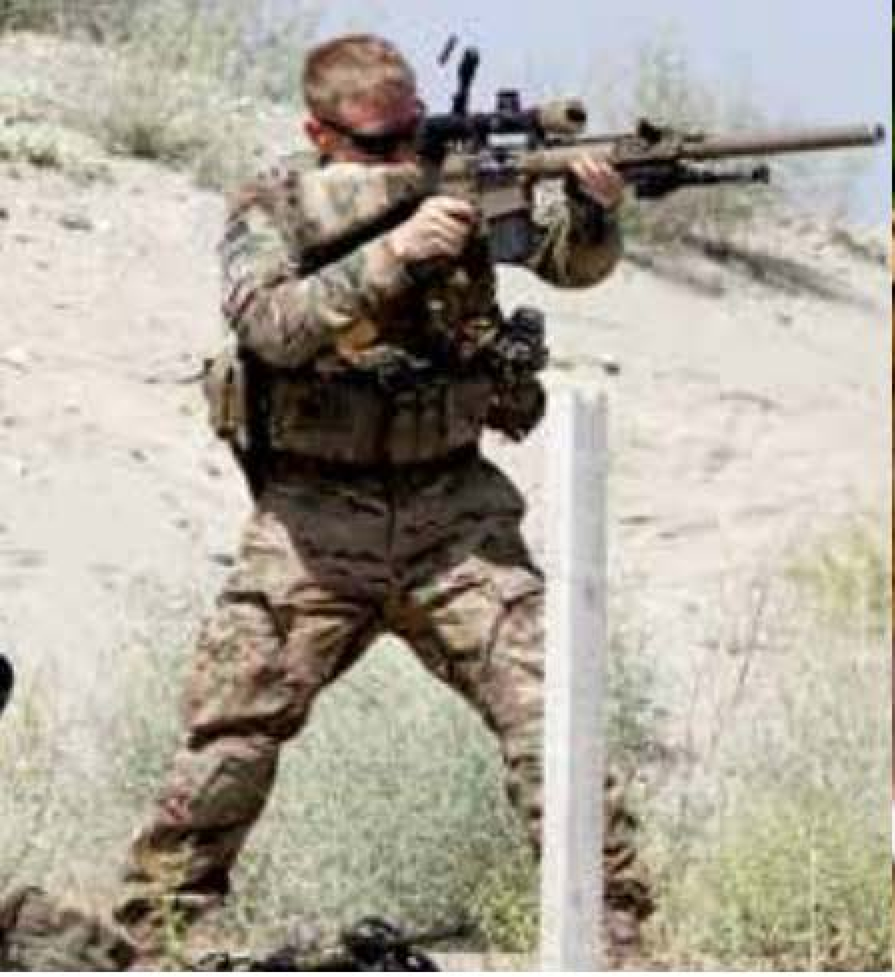
Although rigidity is important, relaxation is also important because the **inherent instability of standing amplifies the effect of any muscle shaking**. As a test of relaxation, a properly relaxed marksman is able to wiggle their toes. Both rigidity and relaxation can be best achieved by keeping the center-of-gravity over one's feet and by visualizing the path that recoil follows (i.e., through the shoulder, through the spine, through the hips, and into the ground).

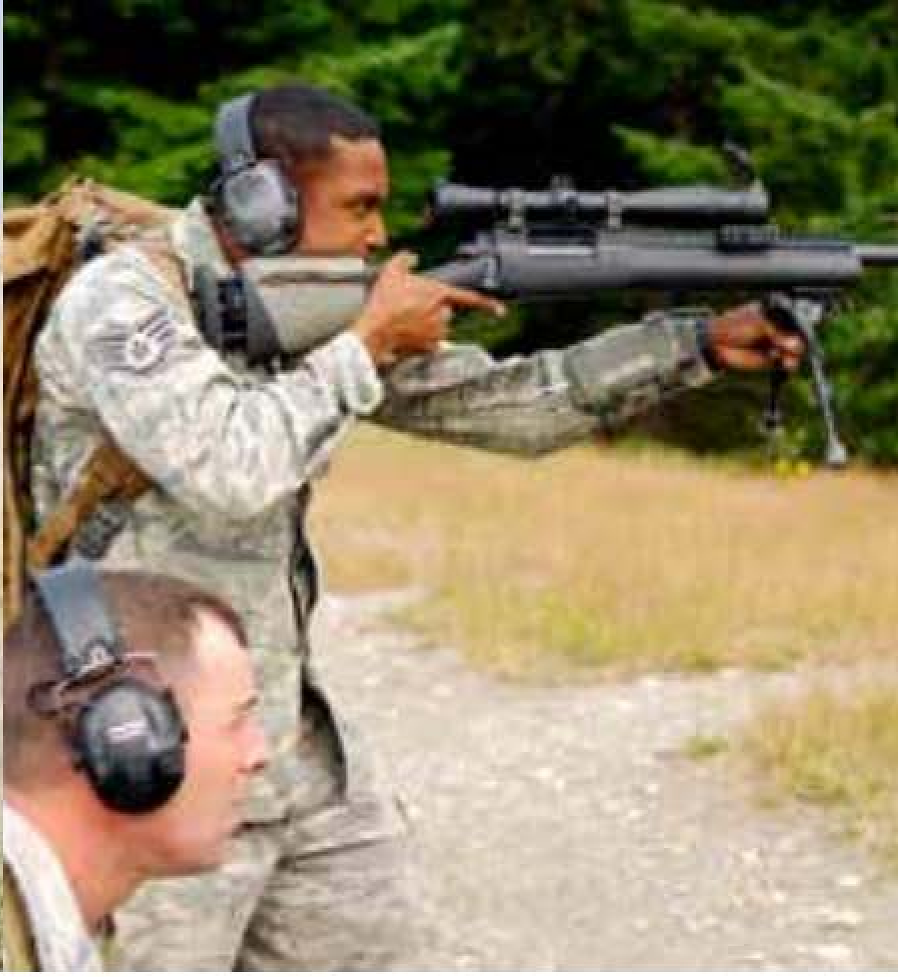
To hold the rifle, a marksman uses the standard technique. (See Holding a Rifle, Pg. 42.) Beyond the standard, the support hand grips the handguard or rail system as far forward as it can while still remaining comfortable and safe. To ensure stability and accuracy while aiming, the support elbow is kept tucked under the rifle stock.

11.d Using a Sling

While some people use the terms "strap" and "sling" interchangeably, they are different items. A rifle strap is a tool that goes around the marksman's body and is attached to the rifle to allow the rifle to be carried. In contrast, a sling is a piece of equipment used to support and stabilize a rifle for more accurate shooting (although it can also be used to carry.) The difference in construction is that **a sling wraps around the back of the marksman's support-arm bicep or shoulder, pulling the rifle into the shoulder pocket** when the marksman pulls their arm backwards. (See Image 73, Pg. 105.)

Because the sling forces the rifle into the shoulder pocket, the support forearm is freed from using pure muscle strength to hold the rifle up and back. Therefore, the support forearm can move into a different position that allows





Standing

Image 71: A 101st Airborne Division sniper squad leader fires at a downrange target while **standing**. Tactical Base Gamberi, Eastern Afghanistan, 05 Jun 2015. His legs are wide, and an observer can follow the path that the recoil force follows: from the barrel, to the stock, to the shoulder, down the body, through the back leg, into the ground.

Image 72: A U.S. Air Force Staff Sergeant of the 615th Contingency Response Wing shoots while **standing**. Joint Base Lewis-McChord, WA, 26 Jul 2011. He leans into the stock while maintaining an upright position with his center-of-gravity over his legs. He holds a bipod leg. His legs are more forward-facing than the marksman to the left.

for more stability or fine movements. In contrast, a strap attaches around the body, does not pull the rifle backwards, and does not free the support arm. Although some marksmen claim that straps improve their accuracy, **there is scant evidence of straps increasing precision since any extra pressure that a strap applies to the rifle risks canting the rifle.** (See Eliminating Rifle Cant, Pg. 144.)

When using a sling, the support arm moves to a position that is as vertically under the rifle as possible. In the prone position, that means moving the support elbow closer to the chin. (See Image 74, Pg. 105.) In the kneeling position, that means moving the support elbow more inside the knee. (See Image 75, Pg. 105.) And in a standing position, that means placing the support elbow on the hip, and the support palm under the forestock. (See Image 76, Pg. 105.)

11.e Using Ground Support

In both unsupported and sling shooting, the marksman's body is between the rifle and the ground. Replacing that human support with a rigid, inanimate support that directly connects a rifle to the ground can increase stability by **bypassing the human element entirely**. Although not always possible, an ideal support allows a marksman to only direct and fire a rifle without using their hands to support it.

When a rifle is supported by something other than the marksman, the marksman is much more free to position their body in whatever way they want to, so long as the principles of shooting are maintained (i.e., stability and relaxation). This flexibility makes it difficult to define a standard supported shooting position. Of course, the starting point is whatever the equivalent unsupported shooting position would be. However to a large degree, the marksman can freely adjust from there. And just as often, they have no choice and are forced into whatever contortion allows them to form a stable support.

That being said, some generalizations can be made. First, ground supports usually **support rifles in the middle** so that they are balanced on the support. This has the side effect of increasing the chance of experiencing muzzle jump, as the rigid fulcrum causes more energy into the rotation about the support. (See Recoil and Muzzle Jump, Pg. 67.) To avoid exacerbating this effect and also avoid bending the rifle components generally, it is bad practice to depress a rifle down into its support with great force. It is also a good idea to support a rifle from the front and the back.

Second, the **best supports can hold a rifle on the target independently** of human intervention. For example, sandbags can conform to the rifle to hold it in position. And most tripods can be adjusted in a way that enables the rifle to be positioned in a particular way. That is not to say that non-independent supports are useless. A rifle using a branch, shelf, or bipod for support is much more stable than a rifle not using any support. However, non-independent supports are still not as rigid as independent supports.

Third, **supports must always be tested before use**. For example, shooting with an impromptu support from any position, such as a rock or a branch, requires actively searching for a spot on that support that allows the rifle to rest without falling. In contrast for example, if the rifle is accidentally put on something slippery, it could slip at any point in the shooting process. This is not always obvious; for example, rotted bark can look stable, but in fact it can slide right off the tree. Even manmade supports require calibration.

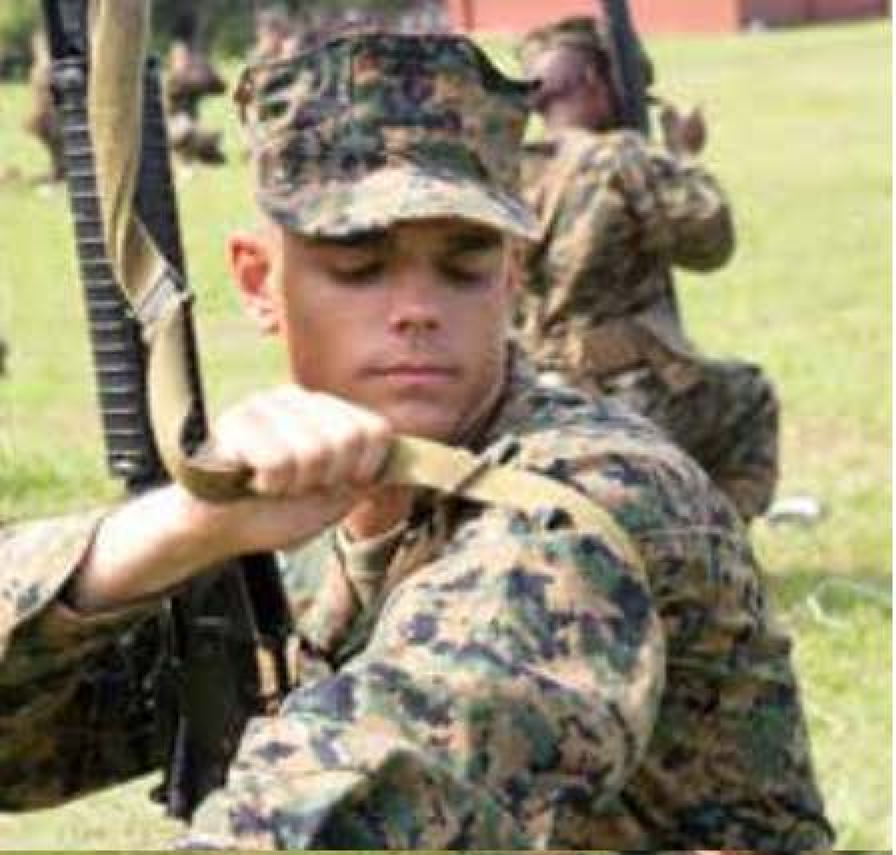


Image 73: A Marine of the 2nd Recruit Training Battalion, tightens his **sling** around his support-arm biceps. Parris Island, SC, 26 Jun 2014. Slings are most often used by combat marksmen and are particularly common among Marines. This is because they are a lightweight way to add precision to shooting. Some hunters also use slings. However, for non-military competitions and hobby marksmen, more secure ground supports are used (if any support is used at all).

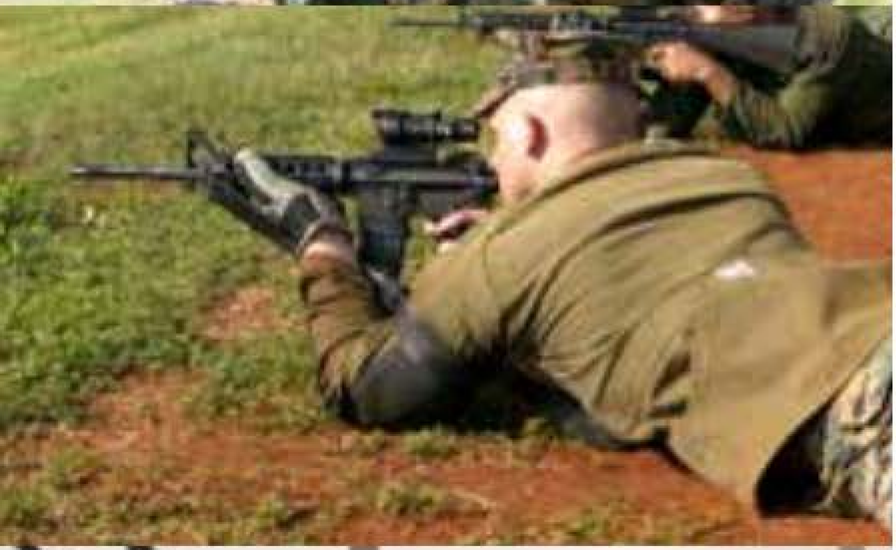


Image 74: Marines fire in the prone position while using **slings**. Ewa Beach, HI, 10 Feb 2014. Using a sling in the prone position is more stable than shooting unsupported, but less stable than resting the rifle on a sandbag. Slings can also severely restrict movement, which is important when shooting moving targets.

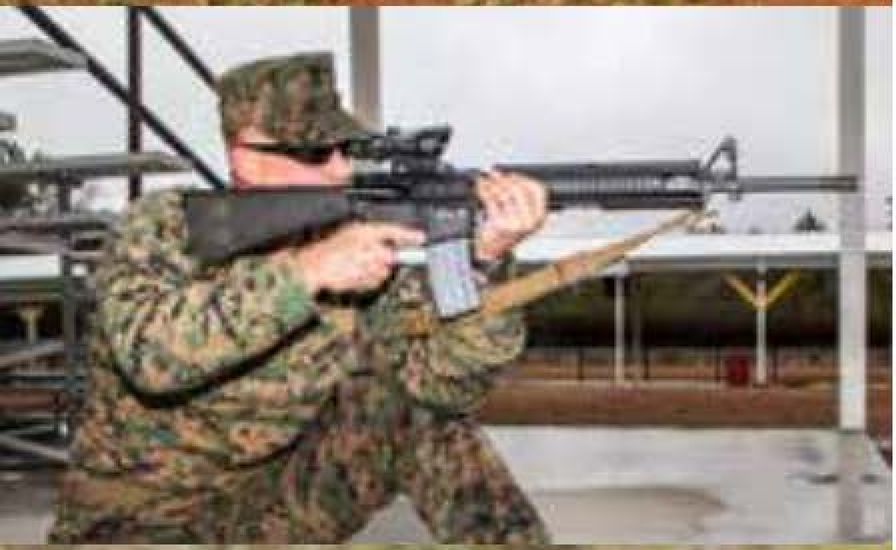


Image 75: A Marine with Weapons Training Battalion, Camp Lejeune, demonstrates a kneeling position with a web **sling**. Camp Lejeune, NC, 10 Feb 2015. The sling allows his elbow to be more interior and support the rifle more vertically from the bottom.

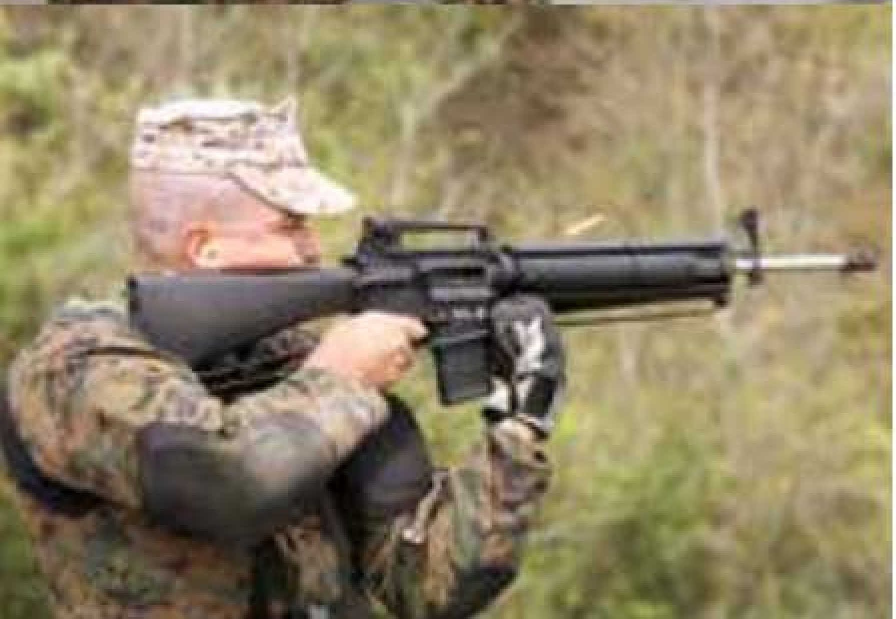


Image 76: A Marine fires his 8 kg (17 lb) M16A4 rifle with a non-slip leather rifle **sling**. Camp Lejeune, NC, 14 Apr 2014. His support arm is directly under the rifle. Some marksmen place their support elbow on their hip. This marksman uses his fist to support the rifle; although other marksmen overturn their fingers to the outside to support with their palm.

Image 77: The most basic supported position is to **put the fore-stock** of the rifle on local objects, such as dirt, rocks, or in this case, sandbags.

Image 78: There are commercial supports called "**sandsocks**," which are lightweight, portable cushions. They can be foam, pellets, or the like.

Image 79: Sandsocks are a staple of shooting because they are always useful for **interfacing the rifle** to a hard surface, no matter the position.

Image 80: Many rifles come with **built-in bipod legs** at the end of the fore-stock. Unlike sandsocks, bipods restrict rotation on uneven surfaces.

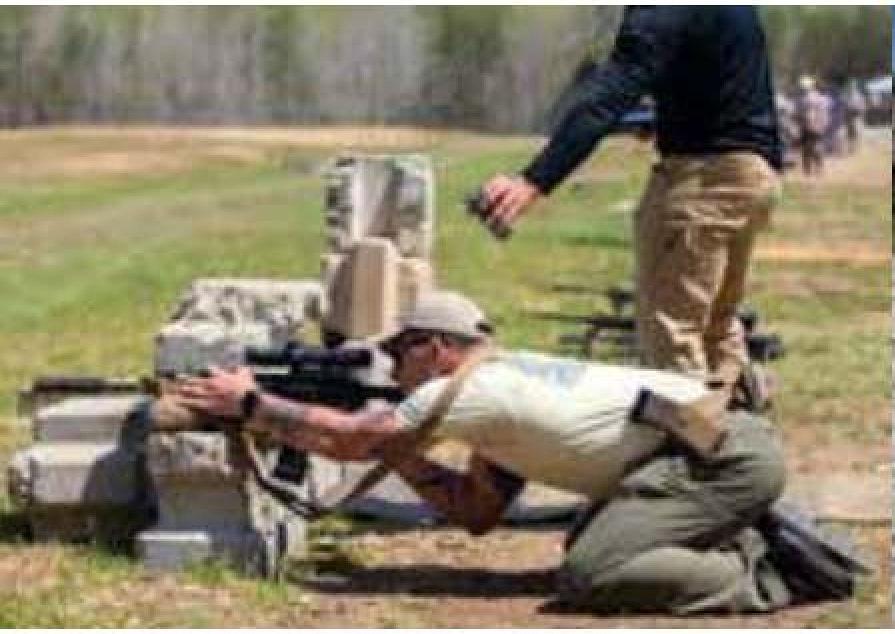


Image 81: If this marksman weren't being timed, he would be better off finding a location where his **center-of-gravity would be over his feet**.

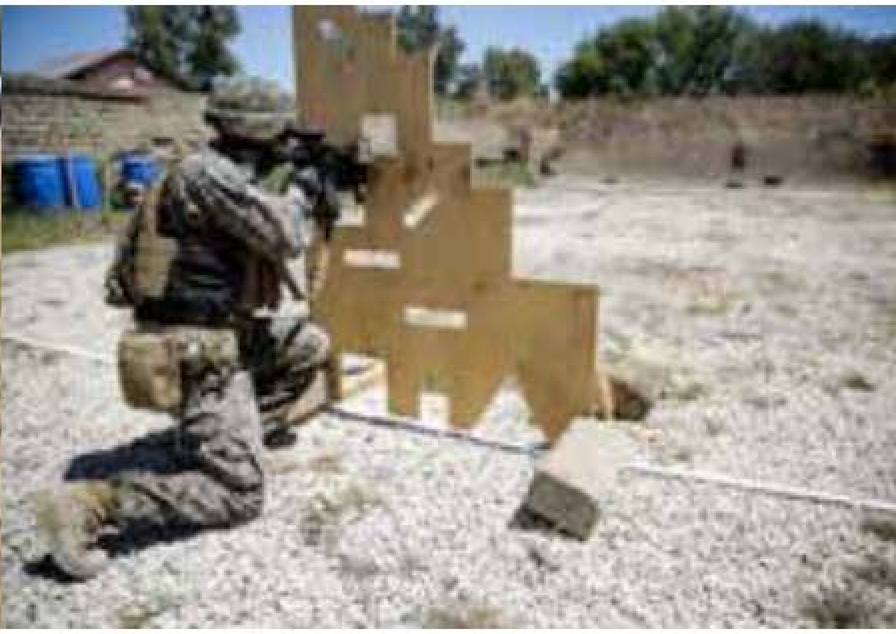


Image 82: This plywood sheet has been cut to allow marksmen to practice using platforms of different heights to **see what works for them**.

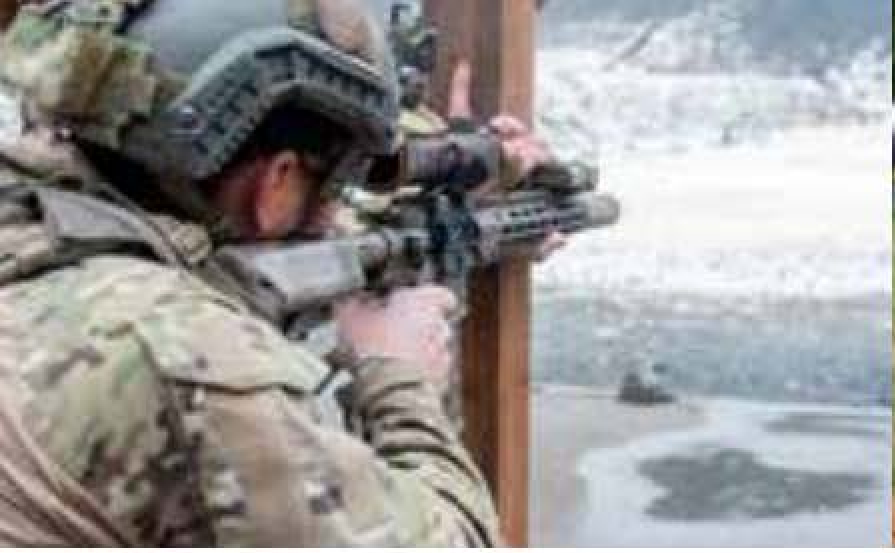


Image 83: A marksman uses a **vertical support** by pushing forward his support hand and using his thumb as a catch. This also works for trees.

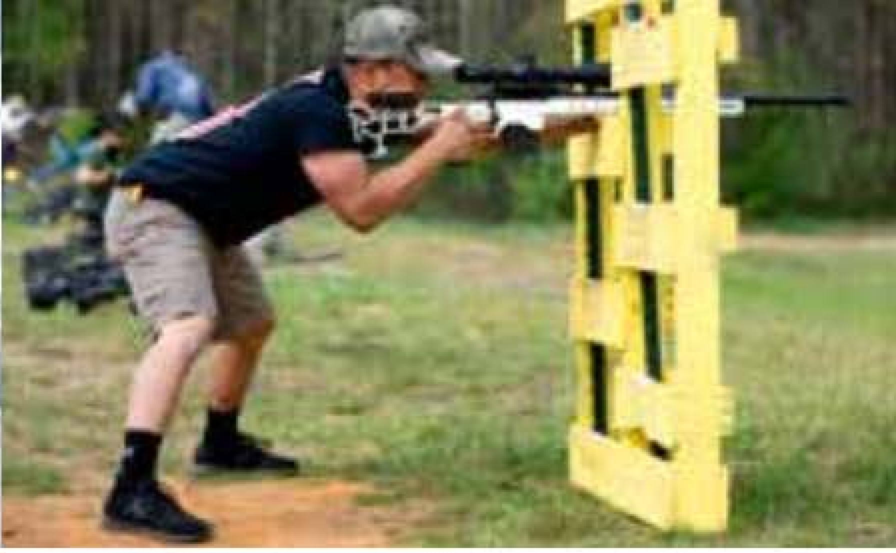


Image 84: This marksman grabs the pallet not to stabilize the rifle, but to **take his weight off the rifle**. Forcing down a rifle decreases its precision.

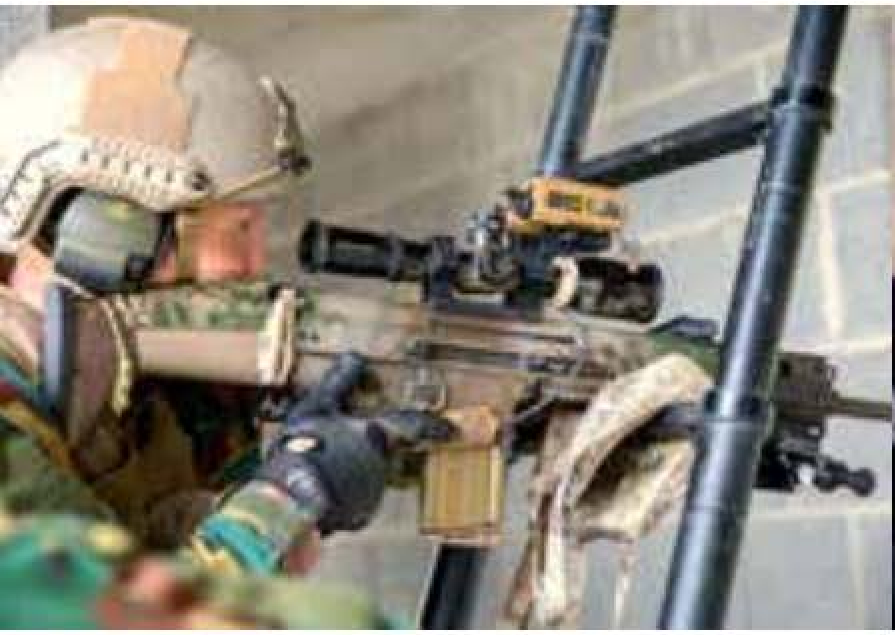


Image 85: Literally **anything can be used as a support** if it is rigid and stable. This marksman uses the ladder he is standing on and a small bag.

OZARK TRAIL

Image 86: Supports are not always about precision. This marksman just wants to be **more comfortable**. All he is missing is a beverage!

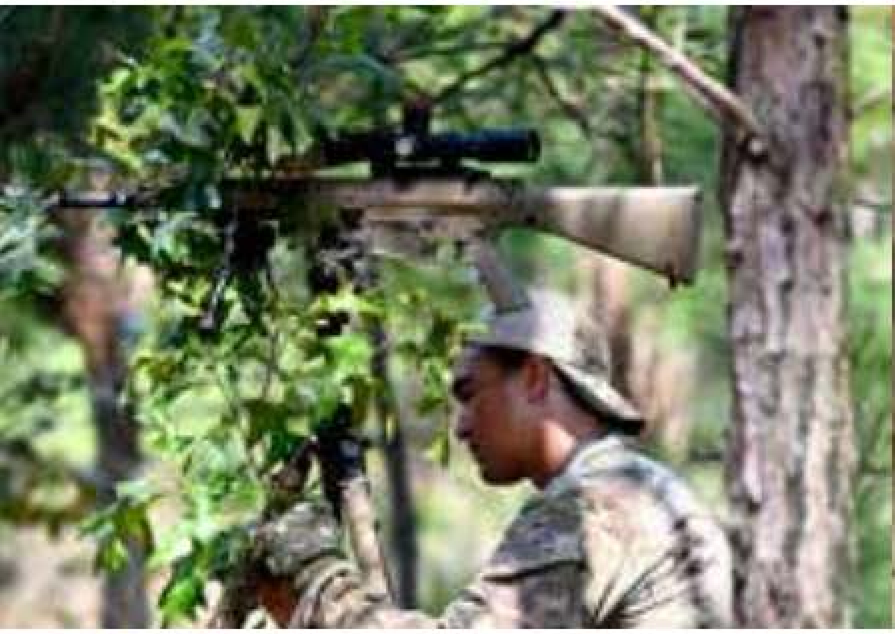


Image 87: A rifle that is set on a tripod can **stand on its own**. Of course, the more stable the rifle, the more difficult it is to adjust.

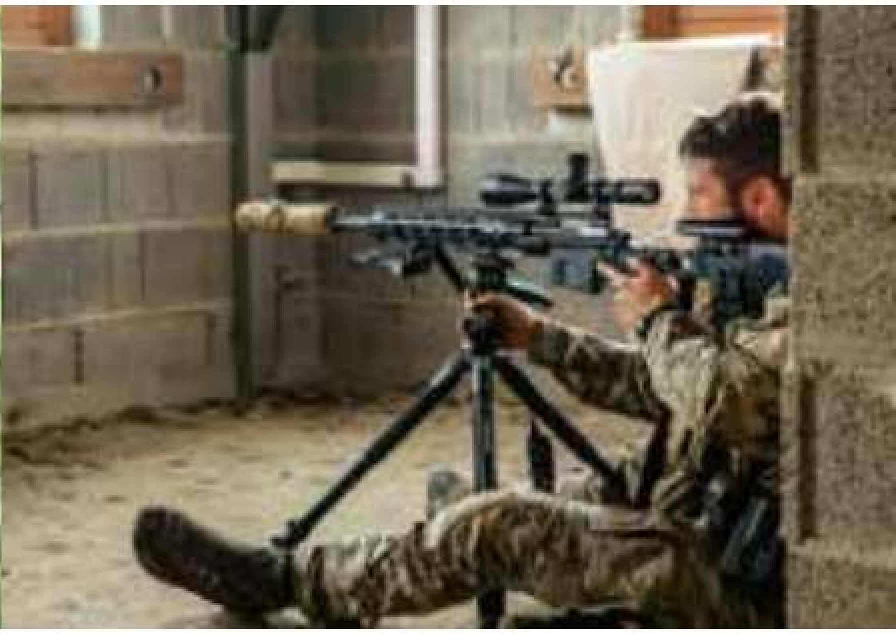


Image 88: Tripods are so stable that **marksmen can take up any position**. This marksman is comfortably sitting. All he needs to do is pull the trigger.

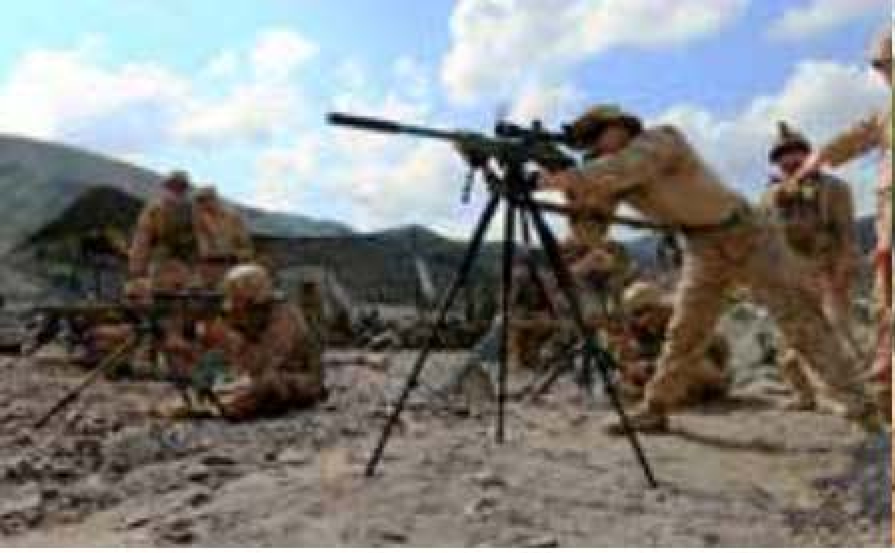


Image 89: The marksman on the right is aggressively leaning forward to **prepare for recoil** and quickly regain their sight picture.

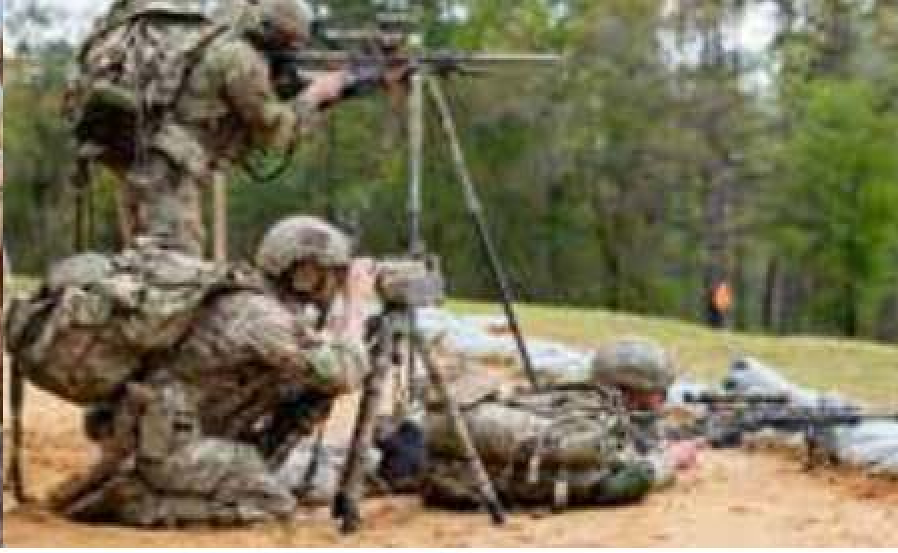


Image 90: The marksman on the left is relatively upright because they are **confident in the stability** of their tripod. They are also wearing a ruck.

Image 91: There is a lot going on here. Sometimes, marksmen must **use whatever is available** to make their shot successful.

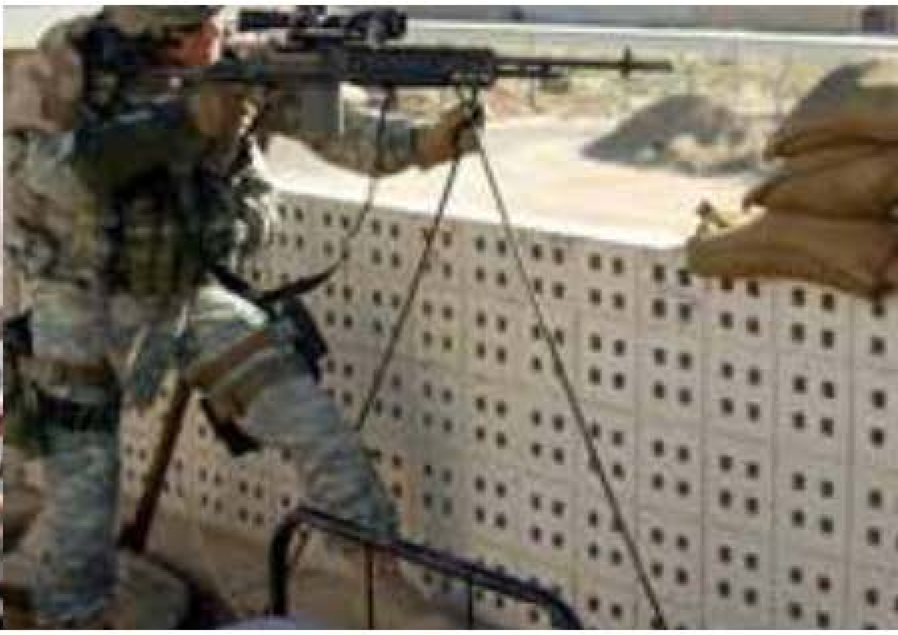


Image 92: Marksmen have always used sticks they find as support. The commercial equivalent is called "**shooting sticks**," as seen here.

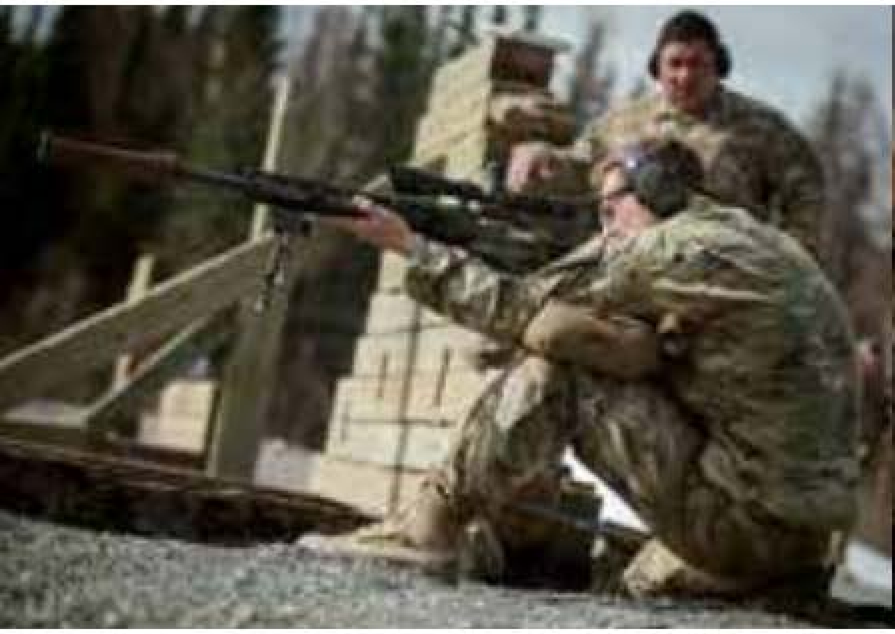


Image 93: Marksmen can **support their "unsupported" shooting positions**. This marksman is using a cushion to stabilize his kneeling.

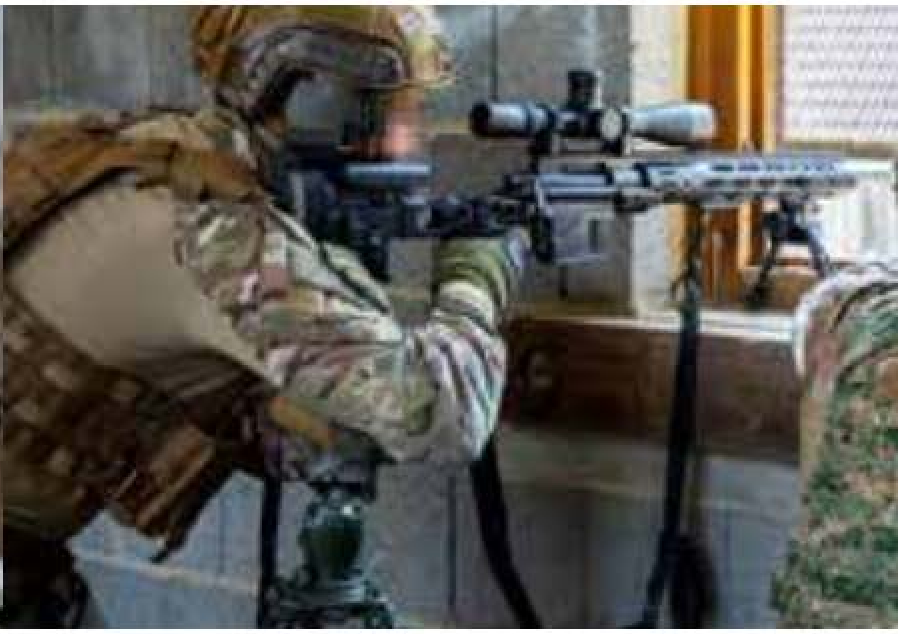


Image 94: This marksman is using a tripod to stabilize his trigger-arm instead of the rifle directly. **This is less stable, but more adjustable**.

Bipod and tripod legs must be the correct height for the marksman, and all the legs must be secured in their position, or else they could randomly slip and make the rifle fall over.

Using a support in the prone position (See Prone, Pg. 97.) is relatively straightforward: a marksman rests the rifle on the support and then uses their hands to operate the rifle in the same way as if the rifle were unsupported. This means that anything, even concrete blocks, can be a prone-position rifle support. That being said, there are two qualities that make for the ideal support: low weight and the ability to conform to the rifle. Both of these qualities are met by a "**sandsock**." (It is so-called because marksmen would carry a sock with them to fill with sand or dirt from around their shooting position and then use the sock to support their rifle.) Nowadays, a rifle support cushion is always called a "sandsock" even though the fabric need not be a sock and the fill need not be sand. Sandsocks come in every conceivable shape and size and it is up to the marksman to decide what to use. For example, more expensive sandsocks are lighter and larger, but many marksmen don't care and simply place their smaller sandsock on local rocks.

In the supported kneeling position, marksmen can use impromptu supports such as a branch or low wall; or they can use manmade supports, such as shooting sticks, a bipod, or a tripod. Again, this means that **a marksman can position themself whichever way allows them to best take advantage of the support to aim the rifle**. For example, the marksman may not need to place their support elbow on their knee to stabilize the weapon. In fact, many marksmen prefer to keep their trigger-side knee instead to support their trigger hand. All this is to say that there are so many supports, body types, and shooting heights that not many generalizations can be made for supported kneeling shooting. For that reason, practicing likely scenarios is the most paramount for this shooting position.

Standing supported is much more stable than standing unsupported, and standing gives a marksman a much better view of their surroundings, so **shooting from a standing supported position is fairly common** when shooting at long ranges. There are rarely natural supports that are exactly the height of the marksman, so most standing supports are manmade, with the most common example being the tripod. Tripods can be adjusted to put the rifle at whatever height the marksman requires. Sometimes rifles have attachment points that connect the tripod directly to the rifle; other times, a marksman may need to place a sandsock on top of the tripod as a platform for the rifle to interface with.

Marksmen can choose their position behind a tripod or other support based on their own comfort and personal stability. The lower body can either stand straight up (See Image 90, Pg. 108.) or bend forward at the waist while leaning into the support (not leaning into the rifle itself!) (See Image 89, Pg. 108.) to better manage recoil. The body can face the support with each leg spread equally in either direction, creating a tripod-like formation between the support and each of their spread legs, or the body can be rotated with the trigger-side leg staggered behind the support-side leg. In either case, **marksmen usually position their feet slightly wider than shoulder-width apart**. And their legs are straight yet relaxed, with their toes pointed towards the target or outwards.

There are a few unorthodox ways to use support. If a marksman has a rifle with an attached strap or sling, they can attach the strap or sling to a support above them, such as a branch, a doorframe, or a window frame, and hang the rifle from above. Also, if there is a wall or side barrier (i.e., a side-support), a marksman can use their support arm to press the rifle into the side-support. This technique is easier if the side-support is on the trigger side; then the marksman can use their support arm to press the rifle into the side support and use their support thumb to support the rifle from the bottom. If the side-support is on the support side of the rifle, the marksman can grab the rifle in their hand as they would in an unsupported position. They then pull the rifle into the side-support, while simultaneously leaning the rifle into the side-support. (See Image 83, Pg. 107.)

12. Finding Distance to a Target

The distance from the marksman to the target is vital information for a marksman to know. It is an important factor in many formulas used in long-range shooting, such as determining how far a bullet travels, and thereby how much time gravity has to pull the bullet down towards the ground. (See Gravity, Drag, and Trajectory, Pg. 128.)

12.a Using Rangefinding Tools

Finding the distance between two objects is a common enough problem that special tools have been invented to do it, such as laser rangefinders and maps.

Laser rangefinders are handheld devices that emit a laser beam that bounces off the target and then calculates the time it takes for the beam to return. The longer it takes for the beam to return, the farther away the target

Rangefinding Tools

Image 95: Modern laser rangefinders are **small and light** enough to be carried and used as a part of any setup.

Image 96: While they have recently fallen out of use, **physical maps** were used for hundreds of years to find the distance between different locations.

Rangefinder Errors

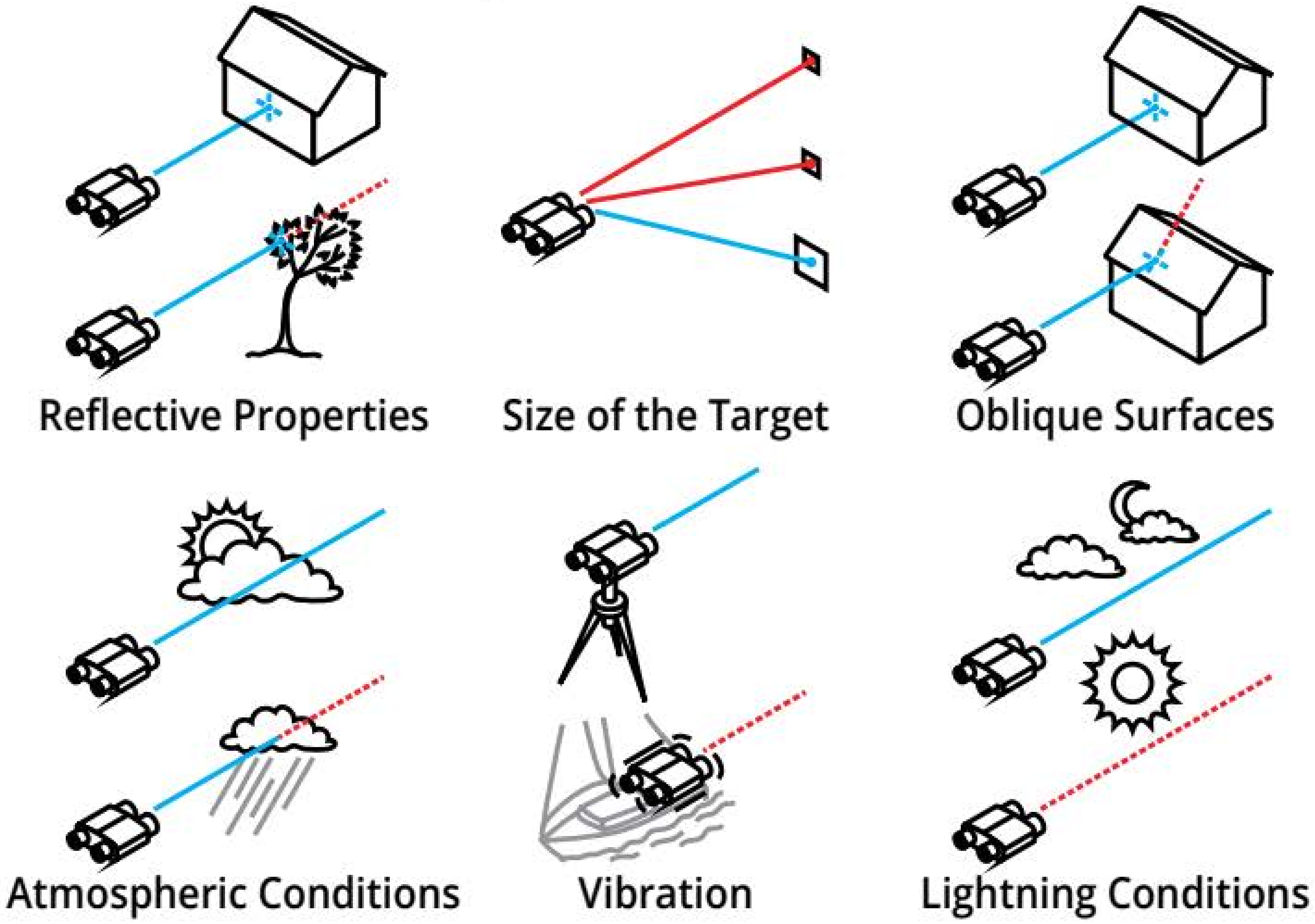

Reflective Properties
Size of the Target
Oblique Surfaces
Atmospheric Conditions
Vibration
Lightning Conditions

Image 97: Laser rangefinders are very accurate, but can give poor readings in certain conditions. This means that **marksmen must take multiple readings,** and then ensure they are all consistent with each other to ensure precision.

is. Because the hardware and software of laser rangefinders are very precise, even less expensive devices can provide distance measurements with errors significantly less than 1% at ranges of 1000 m or yd or less. More expensive rangefinders are of course more precise at farther distances. As with any equipment, marksmen must familiarize themselves with their specific device's instructions and limitations, and practice using it before using it for important events.

Despite their pervasiveness, ease-of-use, and relatively low cost, there are situations where using any kind of laser is inappropriate. The most obvious instance for which a laser rangefinder is inappropriate is during certain military operations. Military operations prohibit the emitting of any signal (including lasers) to the enemy, or else the enemy could detect the origin of the signal and shoot at that location. For these marksmen, specialty technologies such as stereo cameras can determine distance with input light alone. However, no matter the primary means of determining distance, it is recommended to have a rangefinder as a backup (if the marksman can afford one) because being unable to find an exact range is severely detrimental to shooting accuracy.

The more common scenario for not using a laser rangefinder is that some marksmen simply do not like relying on electronics. Such marksmen can use maps instead. **The map method** involves the marksman determining on any map: their own position, the target's position, and the distance between the two. A marksman can pull up Google Maps, measure the distance between them and their target, and use that distance to shoot accurately.

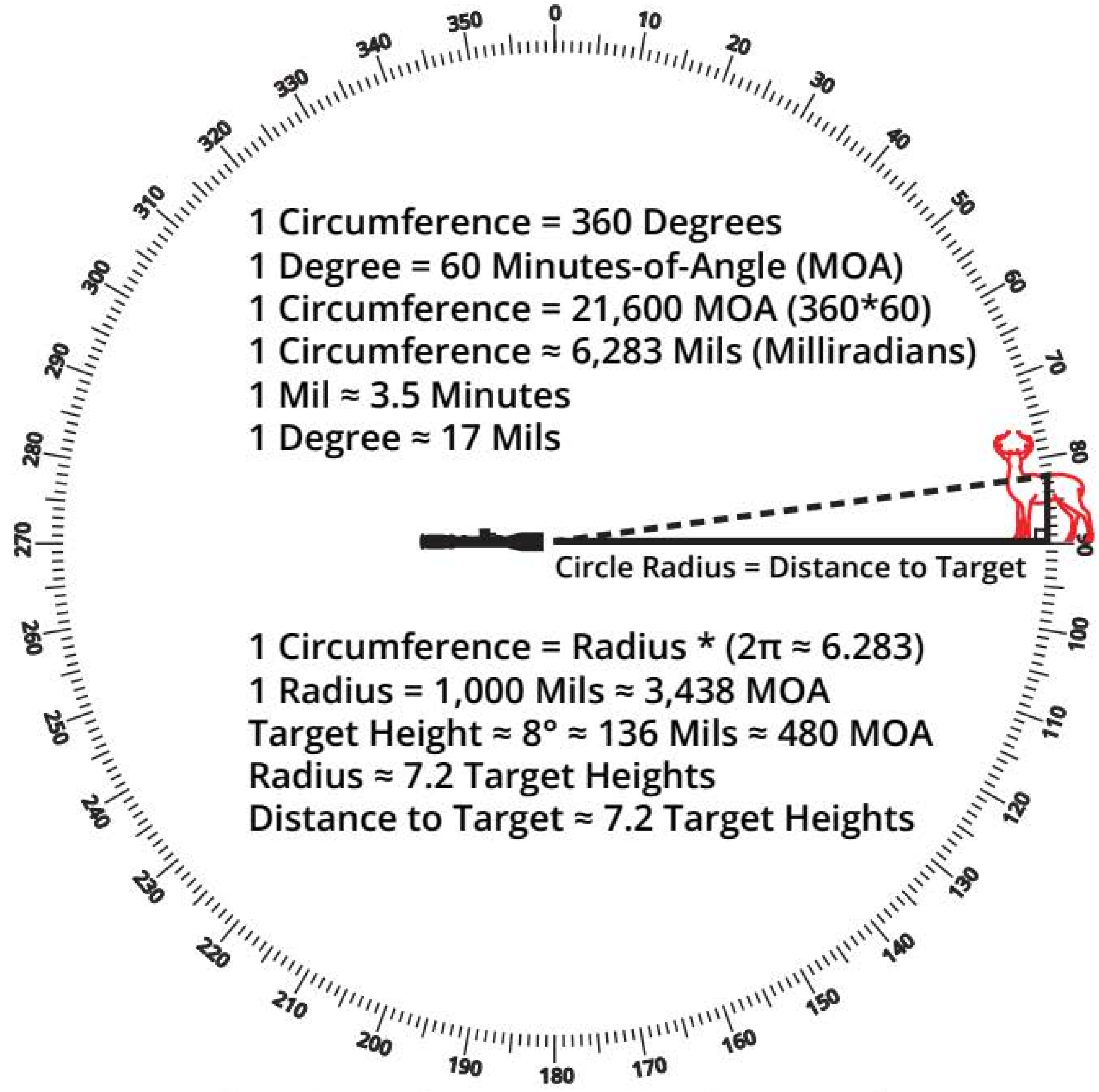
To derive the most accurate measurements from a map, a marksman must exactly know their own position and that of their target. They can determine their own location using a GPS device. Most modern smartphones can output GPS coordinates. If a marksman is able to visit their target, they can store the GPS coordinates of their target to use it as well. If both GPS coordinates are known, the marksman may not even need a map, and can instead use a GPS difference calculator.

12.b Using a Standard Reticle (Milling)

The traditional way that snipers determined distance was through a method called "milling." Milling is not as precise as using a laser rangefinder nor reading a map, but it requires no electronics and is much faster than using a map. Before continuing, to mil (derived from the word "milliradian"), a marksman must be familiar with angular measurements. (See Angular Distance, Pg. 237.) and how to use a standard reticle (See Standard Reticles, Pg. 132.).

Milling works by using a formula with three variables. Any two variables out of the three can be used to determine the third. The three variables are:

Milling Circle



1 Circumference = 360 Degrees
1 Degree = 60 Minutes-of-Angle (MOA)
1 Circumference = 21,600 MOA (360*60)
1 Circumference ≈ 6,283 Mils (Milliradians)
1 Mil ≈ 3.5 Minutes
1 Degree ≈ 17 Mils

1 Circumference = Radius * (2π ≈ 6.283)
1 Radius = 1,000 Mils ≈ 3,438 MOA
Target Height ≈ 8° ≈ 136 Mils ≈ 480 MOA
Radius ≈ 7.2 Target Heights
Distance to Target ≈ 7.2 Target Heights

Image 98: For milling, the marksman is always at the center of a giant imaginary circle. The radius of the circle is the distance to the target. The target occupies a certain percentage of the circle's circumference, which is denoted in either MOA or mils. For example, **in this diagram, the deer occupies 8 degrees, 480 MOA, and 136 mils.** A deer that is 1 m tall would have to be 7.2 m away to appear this large.

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1) Angular distance that an object occupies in a sight picture. This is measured (a.k.a., milled) with a reticle. For example, if a deer is between 9 hashmarks (i.e., occupies 8 subtensions) in a reticle that uses mils, its angular distance is 8 mils. (See Image 98, Pg. 113.)

Angular distance is always an observed variable and can be used with target height to determine target distance, or with target distance to determine target height.

Understanding that mils can be used to measure angles is confusing because most students are only taught to measure angles in degrees; that is, a circle has 360°. However, minutes-of-angle (MOA) (1 degree has

60 minutes) and mils can also be used to measure angles, just like meters and yards are both different measures of linear distance. It may help to know that a mil equals about 1/17 of a degree or about 3.5 MOA.

2) Target linear height (a.k.a., "height") is how tall the target is in meters or yards. Height is almost always used because reticles have vertical hashmarks and heights are easy to find. However, any observable dimension can be used, including width. (See Image 99, Pg. 115.) (See Image 100, Pg. 115.)

3) Target linear distance (a.k.a., "distance") is how far the target is to the marksman in meters or yards. (The process of milling is easier in meters because height is usually measured in feet and inches, which is a pain to convert to yards.)

The concept of milling is best explained using the geometric concept of a giant circle, with the marksman in the middle. The distance to the target is the circle's radius. The target height occupies an arc of the circle (an arc is a length on a circle's perimeter between two points). The angular distance of this arc can be measured in mils or MOA. (See Image 98, Pg. 113.)

Milling exploits a geometric fact of circles: **the linear relationship between a specified circle arc (i.e., the milled angular distance) and the circle's radius is fixed**. That is, they expand and shrink at the same rate, no matter how they are scaled. (See Image 98, Pg. 113.)

This phenomenon can also be explained by the concept that as objects move farther away, they appear smaller because they occupy less angular distance in the marksman's field-of-vision. For example, if the distance to the target is doubled, the apparent size is halved accordingly, and vice versa. For example, a target at 100 m would appear twice as large if moved to 50 m, and half as large if moved to 200 m.

Object Height Examples

Object:	Height:
Door	2.0 m (6 ft, 7 in)
House Wall, External	2.6 m (8 ft, 4 in)
High House Fence	1.8 m (5 ft, 11 in)
Picket Fence	0.9 m (2 ft, 11 in)
Farm Fence and Gate	1.1 m (3 ft, 7 in)
House Window Bedroom	1.3 m (4 ft, 3 in)
House Window Bathroom	1.0 m (3 ft, 3 in)
Toyota Hilux	1.8 m (5 ft, 11 in)
Average Car	1.4 m (4 ft, 7 in)
Concrete Block	0.2 m (0 ft, 8 in)
Brick	0.1 m (0 ft, 4 in)
Garage Door, Single	2.0 m (6 ft, 7 in)
Road Sign	0.9 m (2 ft, 9 in)
Stop Sign from Ground to top	2.1 m (7 ft, 0 in)

Image 99: Observers who mil are familiar with the height of common objects. Objects with global standard height, such as concrete blocks, Hiluxes, or oil barrels, are more useful than customizable objects, such as fences.

Deer Height Examples

Species:	Average height at shoulder:
Roe Deer	0.70 m (2 ft, 4 in)
Sika Deer	0.83 m (2 ft, 9 in)
Fallow Deer	0.90 m (2 ft, 11 in)
White-tailed Deer	0.93 m (3 ft, 1 in)
Mule Deer	0.93 m (3 ft, 1 in)
Reindeer (Caribou)	1.18 m (3 ft, 10 in)
Red Deer	1.22 m (4 ft, 0 in)
Elk (Wapiti)	1.35 m (4 ft, 5 in)
Moose	1.75 m (5 ft, 9 in)

Image 100: Hunters who mil are familiar with the height of their prey.

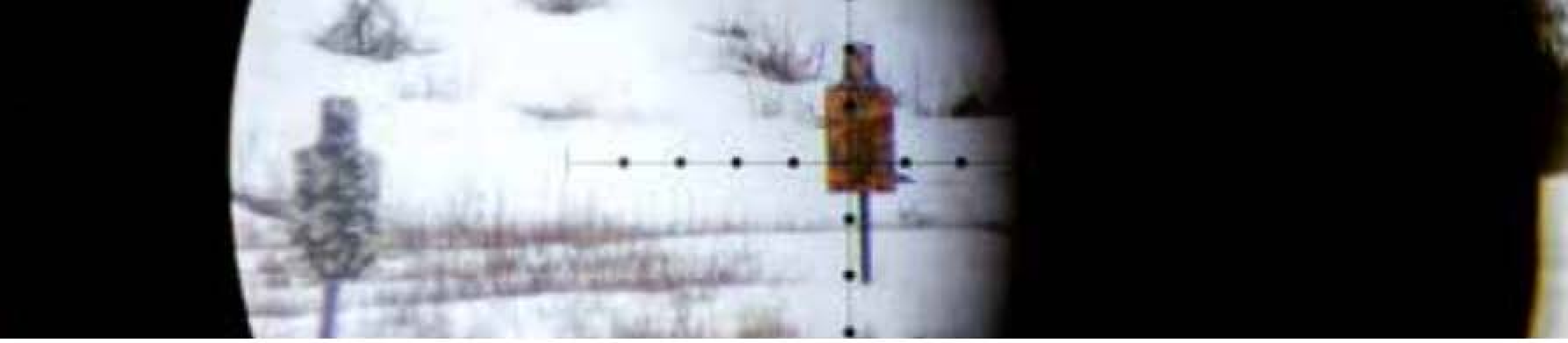


Image 101: This target occupies 2.6 mils on the reticle. From the center, it extends a little more than 2 dots up, and a little more than 0.5 dots down. E-type targets (i.e., the targets in the picture) are standardized to 101.6 cm (40 in) tall. Using the formula:
(D to T) = *(T Height)* ÷ *(T Angle in Mils)* × 1,000
(D to T) = 101.6 cm ÷ 2.6 mils × 1,000
(Distance to Target) = 39076 cm ≈ 391 m (428 yd)

Image 102: This shed occupies 2.5 mils on the reticle. Assume the shed is found to be 1200 m (1312 yd) away with a laser rangefinder. To find the shed height using the formula:
(T Height) = *(D to T)* × (T Angle in Mils) ÷ 1,000
(T Height) = 1200 m × 2.5 mils ÷ 1,000
(Target Height) = 3 m (3.3 yd)

To calculate the distance to the target using a mil reticle requires the following:

Variables:

- **Mil constant** = *1,000*
- **MOA constant** = *3,438*
- **Target Angle** *(T Angle)* = The angle of the target as measured in a reticle in mils or MOA.
- **Distance to Target** *(D to T)* = Distance from the marksman to the target. Both *(D to T)* and *(T Height)* must use the same linear units, such as meters or yards.
- **Target Height** *(T Height)* = The height of the target. (Again, while nominally height, this can actually be any dimension that is perpendicular to the marksman, and is measurable or known.)

Person Height to Distance Table

Height of person in mils	Distance of a standing, 168 cm (5 ft, 6 in) person	Distance of a standing, 183 cm (6 ft, 0 in) person	Distance of a kneeling, 168 cm (5 ft, 6 in) person	Distance of a kneeling, 183 cm (6 ft, 0 in) person
1.0	1646 m (1800 yd)	1829 m (2000 yd)	823 m (900 yd)	914 m (1000 yd)
1.5	1097 m (1200 yd)	1219 m (1333 yd)	549 m (600 yd)	609 m (666 yd)
2.0	823 m (900 yd)	914 m (1000 yd)	411 m (450 yd)	457 m (500 yd)
2.5	686 m (750 yd)	732 m (800 yd)	343 m (375 yd)	366 m (400 yd)
3.0	549 m (600 yd)	609 m (666 yd)	274 m (300 yd)	304 m (333 yd)
3.5	470 m (514 yd)	522 m (571 yd)	235 m (257 yd)	262 m (286 yd)
4.0	411 m (450 yd)	457 m (500 yd)	206 m (225 yd)	229 m (250 yd)
4.5	366 m (400 yd)	406 m (444 yd)	183 m (200 yd)	203 m (222 yd)
5.0	329 m (360 yd)	366 m (400 yd)	165 m (180 yd)	183 m (200 yd)
5.5	299 m (327 yd)	333 m (364 yd)	151 m (165 yd)	166 m (182 yd)
6.0	274 m (300 yd)	304 m (333 yd)	137 m (150 yd)	153 m (167 yd)
6.5	253 m (277 yd)	282 m (308 yd)	127 m (139 yd)	141 m (154 yd)

Image 103: When milling, getting the height of a target wrong can lead to a significant error in the estimate of the distance to the target. However, these averages can be used if there is an acceptable ranging error of 20%, since almost all human heights are within 20% of one of the two categories.

Formulas for mils and MOA to **calculate the distance to the target**, *(D to T),* with a known *(T Height)* and an observed *(T Angle)* are:

- *(D to T) = (T Height) ÷ (T Angle in Mils) × 1,000*
- *(D to T) = (T Height) ÷ (T Angle in MOA) × 3,438*
- (See Image 101, Pg. 116.)

The milling formula can be reversed to determine an object's dimensions, an ability that a rangefinder does not have. With a laser rangefinder and accurate milling, the dimensions found can be extremely precise. The formulas for mils and MOA to **calculate an object's dimensions**, *(T Height),* with a known *(D to T)* and an observed *(T Angle)* are:

- *(T Height) = (D to T) × (T Angle in Mils) ÷ 1,000*
- *(T Height) = (D to T) × (T Angle in MOA) ÷ 3,438*
- (See Image 102, Pg. 116.)

Observing a target's angular distance (i.e., its height in mils or MOA) requires considerable precision while holding the reticle as steadily as possible. An observer must use decimal-point fractions, and consider, for example, whether a height is precisely 1.0 or 1.1 mils. This is because being off by 10% in the measurement of the target's angle translates to being 10% off in the target's distance. Such precision is vital because at far distances, a bullet can drop fast due to gravity. For example, a bullet may drop over a meter from 900 to 1000 m or yd. That means a 10% error would cause a marksman to aim over a meter higher or lower than their desired point-of-impact.

This is especially relevant when the linear height of the target is an estimate, such as with human height. **While "standard" height is a single number, actual humans have a range of heights.** (See Image 103, Pg. 117.)

To mitigate the difficulty of measuring a target's height with a reticle, observers use the edges of hashmarks rather than their centers. This is particularly useful when using mil-dot reticles, where it is easier to align a specific edge rather than trying to keep the edge of the target precisely in the middle of the dot. (See Image 115, Pg. 133.) Another method to improve estimates is to calculate from multiple dimensions, such as measuring height and width instead of height alone. Similarly, if the heights of multiple objects at the same distance are known, measuring all of the objects in the area and calculating their average provides a more accurate estimation.

Targets are not always aligned perpendicularly with the marksman's sightline and can appear at an angle. Sometimes a marksman may be looking down at a target from a higher vantage point; other times they may observe a target from the side. Angled targets appear shorter or narrower than their actual size. If the angle of the target is known, trigonometry can be used to determine the actual angle. However, since the actual angle is rarely known, estimations are usually more practical. For example, if a perpendicular target appears to be 100% of its true width, a target turned to 30° appears as 87% of its true width, 45° appears as 71%, and 60° appears as 50%. For example, if a target appears to be 0.7 mils wide but is angled at 45 degrees, its true width is approximately 1 mil (i.e., $0.7 \div 71\% \approx 1$). This relationship is determined by the cosine of the angle. (See Image 178, Pg. 210.)

In stressful situations, it is inadvisable to perform any calculations. To avoid doing algebra under stress, marksmen can carry a small calculator and premade conversion cards. For example, the Mildot Master (a cheap, brand-name product) is available in metric (height in m ÷ distance in m), imperial (height in ft ÷ distance in yd), and mixed (height in ft ÷ distance in m). (See Image 177, Pg. 209.)

12.c Using Hands

To measure angular distance. An observer can use their **fully outstretched** hands and fingers. When a body part is fully outstretched it always takes up a set amount of angular distance (i.e., mils or MOA) in the observer's vision. With one eye closed, the marksman then aligns the bottom of their body part with the base of the target.

While each body part can only be used to measure one angular distance, an observer may use their multiple body parts, such as their thumbnail, the height of all five fingers, a few finger joints, and even parts of a pen, to determine the distance to a standing target. If the target is larger than the body part, the marksman can simply use a different, larger body part. Or if they are more comfortable with one body part, often the thumb, they can stack thumbnail heights together by moving their thumbnail up in intervals. Conversely if the target is smaller, the marksman can use a fractional percent of the body part, such as one-half or one-third.

To use the thumbnail as an example, an average, fully-outstretched thumb occupies approximately 30 mils or about 120 MOA (**these numbers are just examples, and heavily depend on an individual's personal body proportions**). Therefore, if an object appears to be the same width of a thumbnail, it would be 30 mils wide. Angular distance can be used as a relationship between the distance to the target and the height or width of the target. In this case, a 30-mil-tall object would be 30 m tall at 1000 m away, 15 m tall at 500 m away, or 3 m tall at 100 m away. That is, given the same angular measure, an object at half the distance would be half the height, and one at double the distance would be double the height.

This method uses the same formulas as milling, but with a different constant at the end. That is, formulas to calculate *(D to T)* with a known *(T Height)* and an observed *(T Angle)* may include:

- For mils: *(D to T) = (T Height) ÷ (T Angle in Mils) × 1,000*
- For MOA: *(D to T) = (T Height) ÷ (T Angle in MOA) × 3,438*
- For pinkies: *(D to T) = (T Height) ÷ (T Angle in pinkies) × 70*
- For thumbs: *(D to T) = (T Height) ÷ (T Angle in thumbs) × 33*

The constant for thumbs (33), for example, was found by dividing the constant for mils (1000) by the assumed mils-per-thumb ratio (30) so that 1000 ÷ 30 ≈ 33. The same math is done to find the constant for any object.

Using Hands to Measure Angles

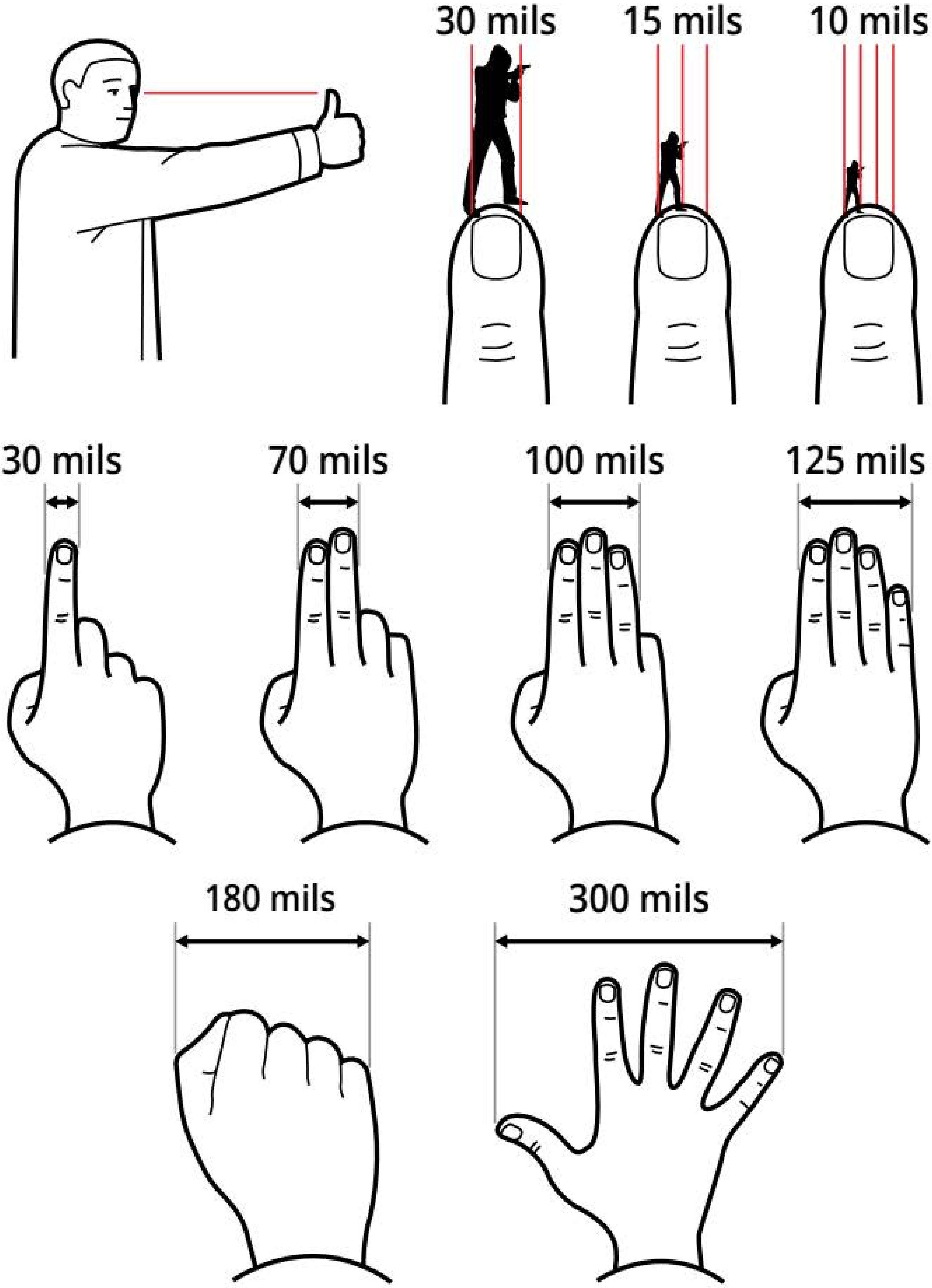


Image 104: Body parts can measure angular distance in either mils or MOA. First, the hand is always outstretched to ensure every measure is consistent. Then the width of the body part (e.g., thumb or finger(s)) is compared against a reticle. Once the conversion factor is known (e.g., 30 mils to one thumbnail), it never changes. Thereafter, a marksman can use that outstretched body part as a ruler. A marksman can get the measure of multiple body parts for quicker measurements. **Every marksman's body parts are different, and the above are only examples.** (The top right shows thumbs, while the middle left shows an index finger.)

For an observer to most effectively use their hands to mil, they must:

1) know and be able to use the angular distance of many body parts of their hands, such as each finger and fingernail width;

2) be able to accurately estimate midpoints for each body part for small measurements, such as half of a pinky finger; and

3) use a measure that is as repeatable as possible, for example fully outstretching the hand every time so that the body part always occupies the same space relative to the marksman.

12.d Using Estimation

Sometimes a tool is simply not available; however more often, marksmen simply enjoy learning the skill of estimation. Being able to quickly and accurately estimate distance to a target can even a fun skill to practice in everyday life.

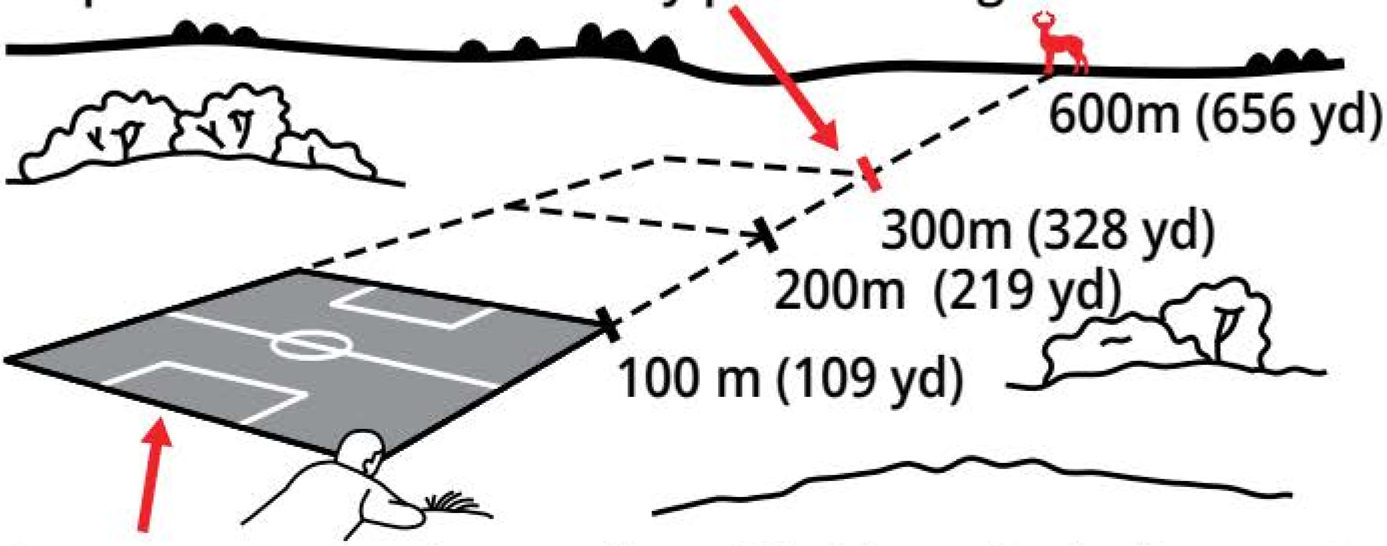
Known-Distance Method – This technique involves comparing the space the marksman is trying to measure to a space they already know the distance of and are familiar with. A common example for Americans is comparing a distance to a gridiron football field. People from other countries may use a soccer pitch. Visual references such as fence posts, power pylons, and telephone poles are especially helpful because they are often spaced at regular intervals that are standard to the local area. For example, a marksman might determine that the distance between their position and the target is equivalent to two football fields or eight power poles away.

Known-distance estimates can be fairly accurate up to around 400 m or yd. However, because a marksman must visualize what their reference distance looks like and also how many of those reference distances it would take to occupy the space, the accuracy of this method strongly decreases over longer distances. This method used to be much more common; however, with the prevalence of GPS today, fewer people have memorized various distances in their life to draw upon.

Mid-Distance Method – One way of extending the distance that an estimate can be is to estimate the halfway point between the marksman and the target and then estimate the distance to that. Alternatively, the estimator can determine the distance from the midpoint to the target. Then the estimator doubles their result to find the total distance from themself to the target. (See Image 105, Pg. 122.)

This method is the most effective when only part of the distance to the target can be easily estimated. For example, a hunter may know the

Using Estimation



Step 1: Estimate the halfway point to target.

Step 2: Estimate the number of fields to the halfway point.
Step 3: Add the lengths of the fields and double it.

Image 105: A marksman can estimate the distance to the target by combining multiple methods. In this diagram, the marksman estimates the halfway point to the target by using the mid-distance method (Step 1 and Step 3) and the known-distance method (Step 2). To get an even more accurate estimate, the marksman can estimate the distance using the appearance-of-things method (Step 4), and average the results from Step 3 and Step 4 using the averaging method (Step 5).

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distance from themself to a pond. If a target is across the pond, they can estimate the partial distance to the pond, and then estimate how many of those partial distances comprise the whole distance.

Appearance-of-Things Method – An observer using this method determines a distance based on how the characteristics of something (e.g., a person, weapon, or vehicle) appear to them. (See Image 106, Pg. 123.) To use this method accurately, marksmen must be very familiar with their own visual observations. Since visibility can vary between individuals due to factors such as biology and experience, each marksman should develop their own visual references instead of relying on others'. Marksmen wanting to develop an expert skill set must create a mental catalog of associations between the appearances of objects at varying distances.

Averaging Method – With the averaging method (a.k.a., "bracketing method") the marksman estimates the minimum and maximum distance away the target could be and then averages them together. (I.e., Average Distance = (Min Distance + Max Distance) ÷ 2) For example, if the marksman estimates a target to be between 440 and 560 m or yd away, then the average distance would be 500 m or yd. (I.e., 500 = (440 + 560) ÷ 2.)

Appearance-of-Things Example

Distance to target:	Common appearance for 20/20 vision:
50 m or yd	Whites of the eyes disappear.
100 m or yd	Blurry eyebrows, eye color, or small wrinkles.
200 m or yd	Blurry hair texture, facial expression, and posture.
300 m or yd	Blurry facial detail, but face color is visible.
400 m or yd	Blurry body detail, but body outline is visible.
500 m or yd	Body shape is vaguely present, but neck disappears.
600 m or yd	Body shape appears wedge-like.

Image 106: How things appear varies significantly from one person to another, so marksmen must experiment at each distance to find what works for them.

Averaging is most effective when using estimates from different sources, such as different people. A common example is averaging the distance between the estimates from a marksman and a spotter on a team. Averaging can also be done by combining estimates from different techniques, such as averaging a known-distance estimate with an appearance-of-things estimate.

12.e Perception Errors

The various methods of estimating distances rely heavily on the marksman's perception of their surroundings. Therefore, if the surroundings change then so do the marksman's perceptions and estimations as well, even if the true distances do not change. In other words, **perception can influence whether an object appears to be closer or farther away than it actually is**.

There are two distinct types of perception errors that a marksman may experience. The first occurs when the target blends in with its surroundings, and there are other surrounding points-of-reference around the target. In these instances, the target may **appear farther away** (See Image 108, Pg. 125.):

- There is an observable depression with visible ground between the observer and the target.
- The surrounding environment is large and dominating, such as near large buildings, cliff faces, or large trees.
- The marksman is lower than the target.
- Targets blend into the background or have irregular outlines, such as a deer in the grass.

Vertical Error from Bad Ranging

Approximate Distance to Target	Approximate Bullet-Drop over 10 m or yd of Horizontal Travel for an Average Rifle System
200 m or yd	0.2 cm (0.1 in)
300 m or yd	1.6 cm (0.6 in)
400 m or yd	3.6 cm (1.4 in)
500 m or yd	6.1 cm (2.4 in)
600 m or yd	8.9 cm (3.5 in)
700 m or yd	12 cm (4.8 in)
800 m or yd	16 cm (6.4 in)
900 m or yd	21 cm (8.2 in)
1000 m or yd	26 cm (10 in)

Image 107: Bullets fall faster as they move farther from the marksman. While the amount of drop may be easy to predict if a precise distance to target is known, even being 10 m or yd off of the actual distance can lead to severe vertical inaccuracy at long distances. For example, this table shows that a bullet would impact about 26 cm (10 in) higher on a target at 990 m or yd compared to a target at 1000 m or yd.

- The sun is behind the target.
- Obscurity from low light (dusk or dawn) or weather (smoke, fog, or rain).
- Moving objects in the environment are scarce, slow, or both.

Conversely, the second type of perception error can occur when the target is highly visible and the surrounding environment is largely vacant. Then, the target may **appear closer** (See Image 109, Pg. 125.):

- There is an unobservable depression between the marksman and the target.
- The surrounding environment is flat and uniform, like a desert plain.
- The marksman is elevated in relation to the target.
- The target contrasts with its background and has a regular outline, such as a house against the sky.
- The sun is behind the marksman.
- There is full sunlight.
- Surrounding objects appear to move fast, such as cars or leaves in the wind.

Perception errors can strongly affect the marksman's accuracy: estimates that are too short cause bullets to hit low, and estimations that are too long cause bullets to hit high. (See Image 107, Pg. 124.)

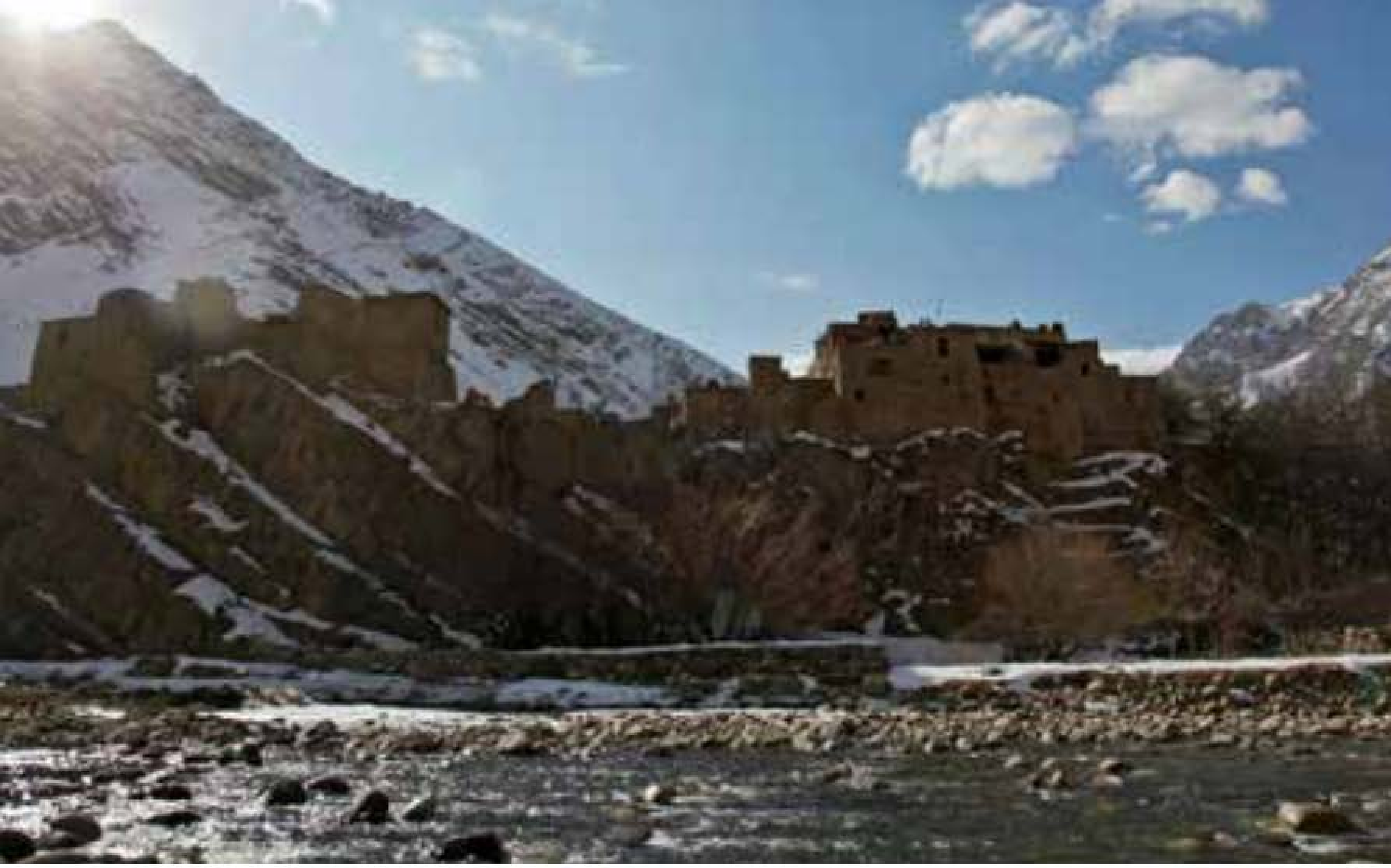


Image 108: The windows in these two images have been roughly standardized to the same size. Despite that, the building in this image **appears farther away** because: the ground is clearly visible all the way to the target; the target is large and imposing; the viewer has a low vantage point; the building outline is irregular, and the sun is behind the target at dusk, thereby lowering the contrast.

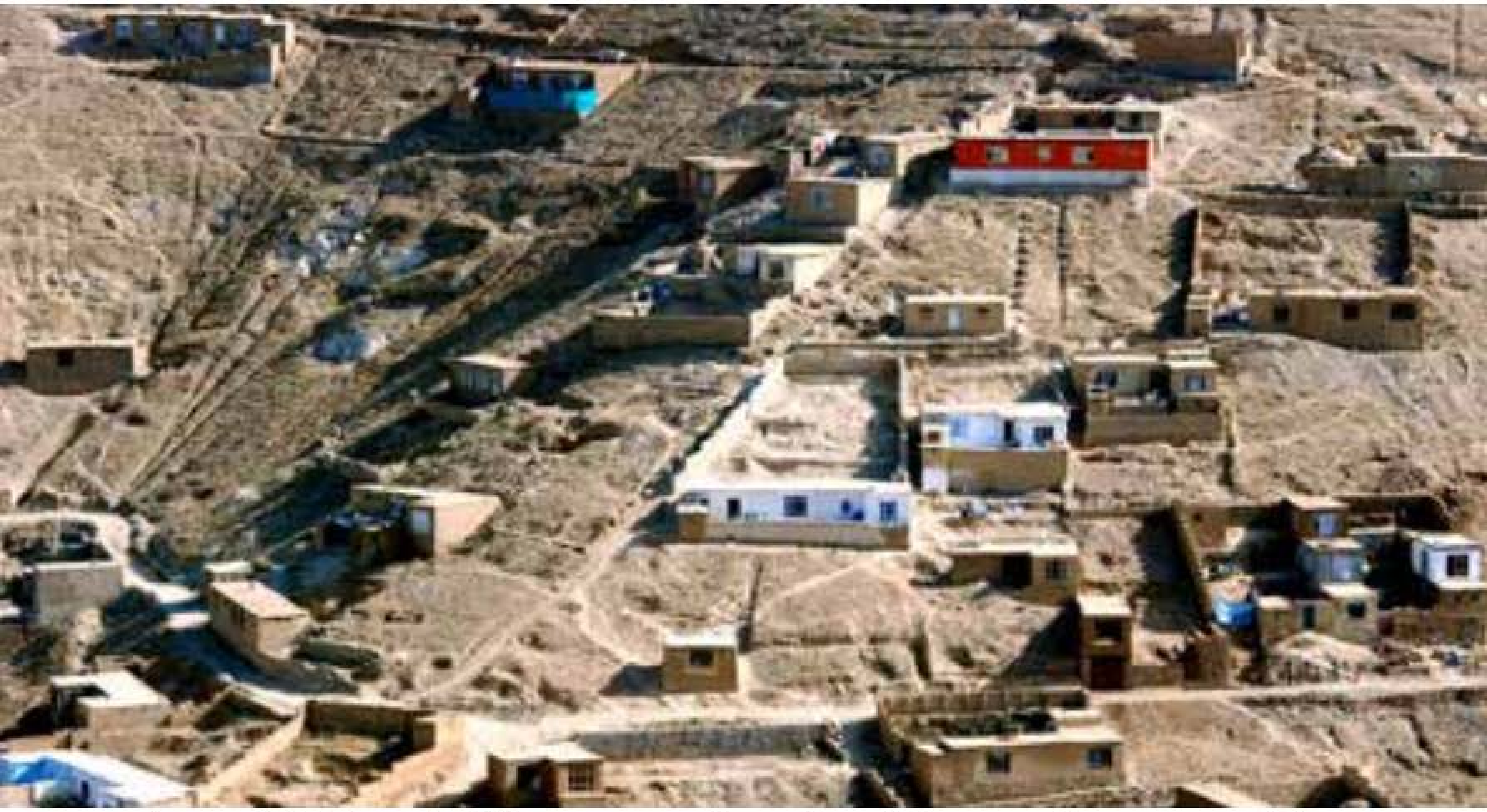


Image 109: These buildings **appear closer** for all the opposite reasons of the above image.

Overcoming perception errors in shooting requires practice. One way to start learning is by becoming familiar with how various objects appear at a standard distance (e.g., at 100 m or yd) under the same conditions. Alternatively, one can overcome perception error by becoming familiar with the same object under various conditions (e.g., raining versus sunny). Natural markers found in the shooting environment, such as distinctive trees in open areas, clusters of rocks in the distance, or patches of grass on open terrain, make for excellent practice objects.

Marksmen begin their practice by estimating distances to random objects in their surroundings and then confirming the distance with a laser rangefinder or GPS device. Once marksmen feel comfortable identifying objects at the standard distance they chose (e.g., 100 m or yd), they can progress to range distances that are progressively farther away from this standard distance. Estimating distances can even become a friendly competition with a partner to see who can come closest to the correct distance.

13. Using Scopes for Long-Distance Shooting

Scopes are essential tools for long-range marksmen. (See Scopes, Pg. 20.) They are a type of sight, which is any device used to assist in precise visual alignment (i.e., aiming) of weapons. To aim with a scope, a marksman uses the scope's internal markings called the "reticle." Because aiming is the primary purpose of a sight, having that reticle is the primary purpose of a scope.

However, what sets scopes apart from other sights is their ability to allow marksmen to overcome two challenges specific to long-range shooting: small targets and gravity. For the former, scopes magnify the image that the marksman sees. Almost all long-range scopes have the ability to make an image at least eight times larger.

For the latter, gravity drops bullets down to Earth. In fact, the distance that a bullet falls as it flies is called its "bullet-drop." To compensate for bullet-drop from gravity, scopes have special features on their reticles and turrets that allow marksmen to readjust their point-of-aim upwards to compensate.

13.a Magnification

Humans can make finer adjustments to their aim than what the naked eye can perceive; therefore, shooting accuracy is limited by the human ability to see.

Image 110: A Marine radio operator with Battalion Landing Team 1st Bn., 4th Marines, 11th Marine Expeditionary Unit, looks through his M8541A optic. This "3-12x50" scope has a magnification range of 3 times to 12 times the naked eye, and has an objective lens 50 mm in diameter. USS Somerset, At Sea 12 Jan 2017.

A key advantage of using a scope is that it magnifies the target, allowing the marksman to see targets in greater detail and therefore utilize more precise aiming adjustments onto smaller targets. (See Target Definition, Pg. 55.)

However, **the drawback to using magnification is that it restricts the marksman's field-of-view**. That is because the ability of the eye to receive information is limited, and any enlargement of one image necessarily covers another part of a person's overall sight. The restricted field-of-view causes various problems, each with their own solution.

First, limiting a marksman's sight can cause the marksman to lose awareness of the situation around them (a.k.a., situational awareness or SA) and make it difficult to track moving targets. These external problems can be mitigated by keeping the second eye open while using the scope. This will help create greater situational awareness since the marksman would be able to discern threats via their peripheral vision. (See Shooting with Both Eyes Open and Eye Dominance, Pg. 92.) However, this requires a lot of practice since the mind tends to concentrate on one image at one time. That's why many marksmen prefer to keep one eye closed while long-range shooting.

Second, a magnified image by definition enlarges an area that is small relative to one's whole vision. Finding a target area or interpreting a mirage pattern (optical distortions of air) (See Simple Mirage, Pg. 191.) with only a small, bounded area takes more time than if a marksman were to use their naked vision. Enlarging a small area also has the side effect of amplifying any trembling of the sight picture. Psychologically, a shakier image can lead to increased trigger jerking and excessive focus on the shaking, even if the actual shaking remains consistent across different levels of magnification. Therefore, scopes are typically carried and used to search at low-magnification settings and adjusted as needed. (See Finding a Target, Pg. 57.)

Third, limiting or altering the image seen by one eye makes it difficult for a marksman to perceive and interpret details that are to the side of the target. For example, if a marksman wants to know the wind speed, they may have to look away from their scope to check a wind indicator; whereas they could see both the target and the indicator at the same time without a scope. There is no solution here but practice, as eventually marksmen learn to be as accurate as possible after they have acquired the necessary information to shoot.

Finally, high magnification can result in mechanical or optical limitations. For example, some manufacturers design scopes with first focal plane reticles that can hide the bottom of the reticle when at maximum magnification settings. (See Image 119, Pg. 137.) Scopes with a small objective lens may show a dimmer sight picture in low-light conditions. And magnification shrinks the eye box. (See Image 28, Pg. 49.) The solution for these issues is easy, although expensive. Marksmen must buy a better scope with a larger objective lens. Although this has a second-order effect of making the scope heavier, so **marksmen always have to balance their preferences for picture-quality, cost, and weight when choosing a scope**. All too often, marksmen overestimate how much magnification they need to purchase.

13.b Gravity, Drag, and Trajectory

Gravity is a pseudo-force that effectively pulls objects together. From the moment a bullet exits the muzzle, it reacts to the Earth's gravity, which accelerates the bullet downward at a rate of $9.81\ m/s^2$ ($10.7\ yd/s^2$). That is, gravity causes bullets to move vertically as they travel, no matter how straight a marksman fires. Therefore, bullets impact at different elevations on targets at different distances. **Scopes help marksmen predict a bullet's elevation on a target based on the distance to the target.** (See Image 116, Pg. 134.)

Acceleration is different from movement. Bullets do initially move upwards because gun barrels are angled upward to ensure that the bullet's path-of-travel (i.e., trajectory) intersects with the scope's sightline. (See Image 111, Pg. 129.) However, after bullets exit the muzzle, they universally accelerate downward, even if they are initially moving upwards. (The lift force from aerodynamics may provide some initial upward force, but it is negligible compared to gravity.) This means that bullets never move higher than the imaginary line that points out of a barrel (i.e., the "boreline").

Actual Trajectory of Bullets

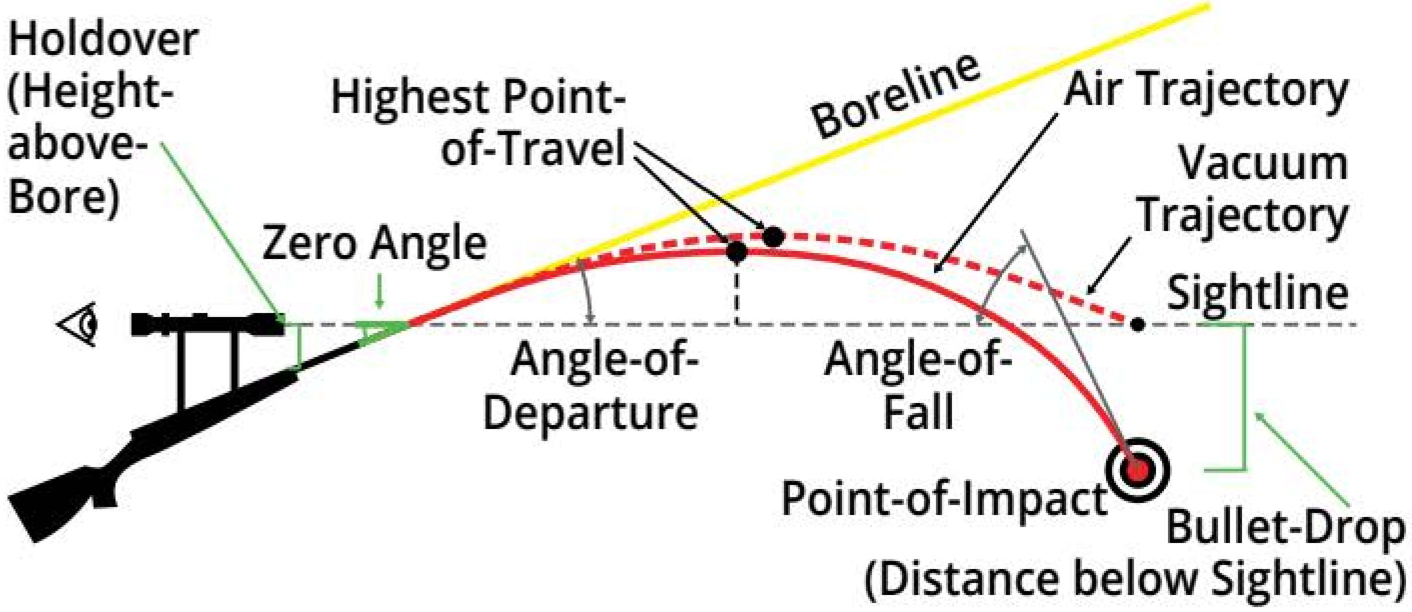

Holdover (Height-above-Bore)
Highest Point-of-Travel
Boreline
Air Trajectory
Vacuum Trajectory
Zero Angle
Sightline
Angle-of-Departure
Angle-of-Fall
Point-of-Impact
Bullet-Drop (Distance below Sightline)

Image 111: Bullets do not follow a straight line, even though they may appear to follow one at short distances. In a vacuum, gravity would make them follow a parabola (i.e., a curve that mirrors about the apex). However in air, they slow down and have a **steeper angle-of-fall than angle-of-departure**. What bullets never do, is rise above the line-of-departure, which is identical to the boreline.

Trajectory Vocabulary

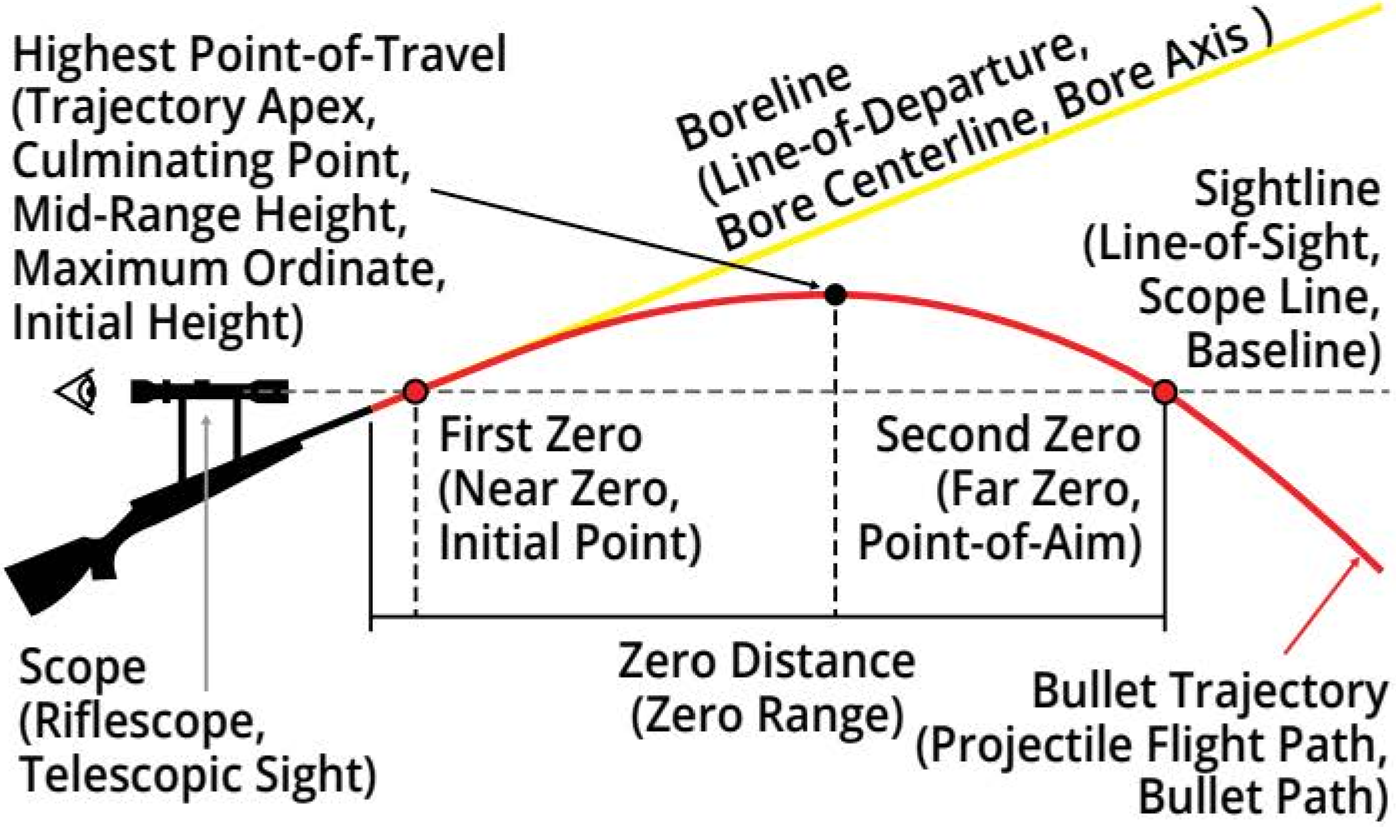

Highest Point-of-Travel (Trajectory Apex, Culminating Point, Mid-Range Height, Maximum Ordinate, Initial Height)
Boreline (Line-of-Departure, Bore Centerline, Bore Axis)
Sightline (Line-of-Sight, Scope Line, Baseline)
First Zero (Near Zero, Initial Point)
Second Zero (Far Zero, Point-of-Aim)
Scope (Riflescope, Telescopic Sight)
Zero Distance (Zero Range)
Bullet Trajectory (Projectile Flight Path, Bullet Path)

Image 112: Because firearm culture has always been decentralized, many concepts have **multiple terms or phrases that mean the same thing**. For example, the sightline can also be called the sightline, scope line, or baseline. There is no good solution but to be familiar with all the terms.

In a vacuum, gravity would cause the bullet to travel in a curved (parabolic) path. However, since bullets are not fired in a vacuum, they are affected by air resistance. The air resistance is the result of bullets having to push air out of the way to move forward, and it is formally called "**aerodynamic force**." (See Image 114, Pg. 131.)

Aerodynamic force is a consequence of Newton's law of equal and opposite reactions; when the bullet pushes on the air, the air pushes back on the bullet. That is, aerodynamic force only exists when an object (e.g., a bullet) moves through a fluid (e.g., the air). While gravity is a consistent force, the aerodynamic force is variable. For example, air density can vary, resulting in thicker or thinner air, leading to higher or lower air resistance. (See Air Density, Pg. 189.)

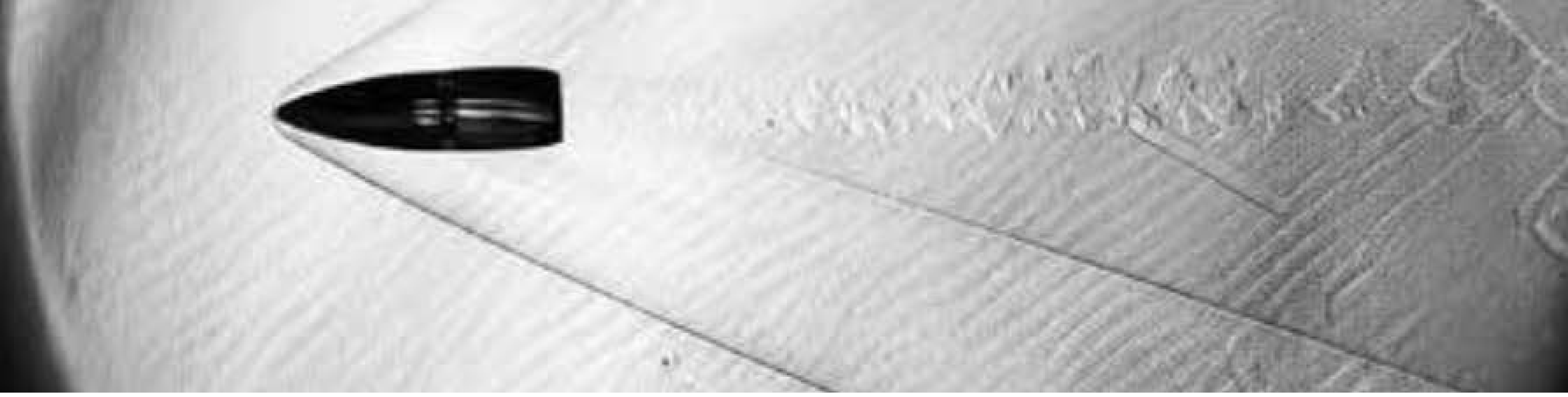
The component of aerodynamic force that slows a bullet down is called the "**drag force**." (Contrary to its name, drag does not pull objects. It is actually the air in front of an object that pushes objects backwards.) In contrast, the component that pushes a bullet off its path-of-travel is called the "**lift force**."

Rifle bullets are designed to minimize the effects of aerodynamic force by slicing through the air with a pointed tip and a thin, long body. Therefore, bullets only experience relatively little drag as they move forward. However, any loss in speed is permanent and cumulative. Therefore, drag effectively accelerates bullets backward, decreasing velocity, even as they move forward. In other words, **bullets slow down as they travel forward.**

As a bullet slows, gravity has more time to pull it downward over a given distance. For example, a bullet may take twice as much time to travel from 900 to 1,000 m or yd as the time it would take to travel from 200 to 300 m or yd. Because of this, gravity has twice as much time to act, causing the bullet to accelerate downwards more over each unit of distance as it travels farther from the marksman. The net effect is that a bullet's trajectory (i.e., its path-of-travel) is not a parabola, but a higher-order curve. (See Image 111, Pg. 129.)

All that being said, it is crucial to understand that bullets always fall at the same speed. A useful thought experiment to illustrate this is to imagine firing a bullet horizontally while simultaneously dropping another bullet from a hand. Both bullets would hit the ground at virtually the same time (the only difference being any insignificant lift forces.)

The trajectory of a bullet can only be altered in three ways. First, a marksman can reduce the amount of time gravity has to act on the bullet by making the bullet move faster. This can be achieved by increasing muzzle velocity with, for example, a higher-powder load or a longer bore.



Interaction of Bullets and Air

Image 113: This bullet was photographed mid-flight to show the effect it has on the air. The curved lines at the front are the bullet's **sonic boom**. The sonic boom does not directly touch the bullet because air sticks to the bullet (a.k.a., the "**air jacket**") as it flies and acts as a barrier. The chaotic air directly behind the bullet is the **turbulence** created from having a flat back. Both of these effects are results of aerodynamic force (i.e., air resistance) acting on the bullet.

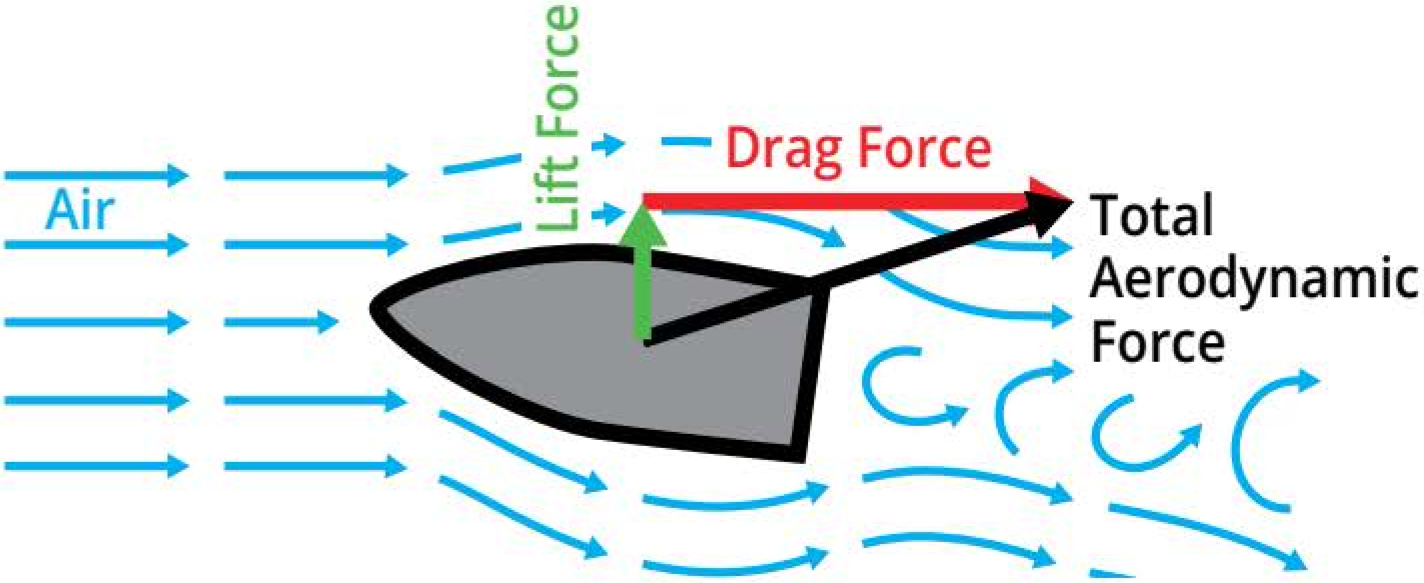


Image 114: When a bullet moves through the air, the air hits the front of the bullet. The force of the air pushing the bullet is called the "**aerodynamic**" force. The aerodynamic force can be broken down into two components: **lift and drag**. Lift force is the amount of force pushing the bullet perpendicular to its direction of movement, while drag is the amount of force pushing the bullet backwards (i.e., parallel to the direction of its movement).

The second method is reducing drag, or in other words, minimizing the force of air resistance. This can be accomplished by altering the physical shape and surface of the bullet, allowing it to travel more efficiently through the air.

Finally, the mass of the bullet can be changed, which has an interesting effect on its trajectory. Bullets with more mass (a.k.a., heavier bullets) have more inertia, and so they traverse a bore and exit the muzzle at slower speeds. However, because more mass travels slower, they have more time to absorb energy from exploding gases in the bore and so retain more energy to resist air resistance. This means that, everything else being equal, bullets with more mass travel slower at the start but faster at the end of their trajectory compared to bullets with less mass. In other words, bullets with more mass have more curved trajectories at closer distances and flatter trajectories at farther distances. (I.e., their trajectories curve down or decelerate more slowly.)

13.c Standard Reticles

A reticle is a **pattern of lines, dots, or markings** that can be seen within an optical sighting device (e.g., scope, binoculars, rangefinder). The simplest and most recognizable reticle design is crosshairs. It consists of one horizontal line and one vertical line that intersect at the center. (See Image 115, Pg. 133.)

The reticle sits in front of the lenses and is used as a reference point(s) when aiming. In other words, reticles are used to align the marksman's point-of-aim (a point on the reticle) with the bullet's intended point-of-impact (the point where the bullet impacts). To ensure this alignment happens, marksmen use the zeroing process (See Zeroing, Pg. 79.)

The center of the reticle only aligns to the point-of-impact at a specific distance (i.e., the zero distance). (See Picking a Zero Distance, Pg. 77.) At other distances to the target, the bullet is higher or lower due to the pull of gravity. (See Image 116, Pg. 134.) Therefore, at different distances to the target, the marksman must aim using a different point on the reticle to achieve the same point-of-impact. To enable precise shooting at the same point-of-impact at different distances, a reticle with multiple markings is necessary.

Each marking on a reticle used for aiming is referred to as a "**hashmark**." Hashmarks on standard reticles are always spaced at set intervals on the reticle and form a repeating pattern. The distance between hashmarks is referred to as a "**subtension**." Each subtension measures an angular distance, such as 1 mil or 1 MOA. (See Angular Distance, Pg. 237.)

All reticles can use either MOA or mil for their angular measurements. Either standard works for a single marksman, although the gun market is shifting towards the mil standard. What is important is that both the reticle and turret use either the mil standard or the MOA standard. Otherwise, turret clicks cannot shift the reticle by whole units (for example, a click of 1 MOA would shift a reticle by approximately 0.29 mils).

All hashmarked reticles have additional hashmarks below the center point. This allows a marksman to choose their point-of-aim from multiple, vertical reference points (i.e., the hashmarks) in their sight picture. This is useful because where the point-of-impact appears in the sight picture depends on the distance that a bullet travels. As bullets travel, gravity pulls them down

Standard Reticles

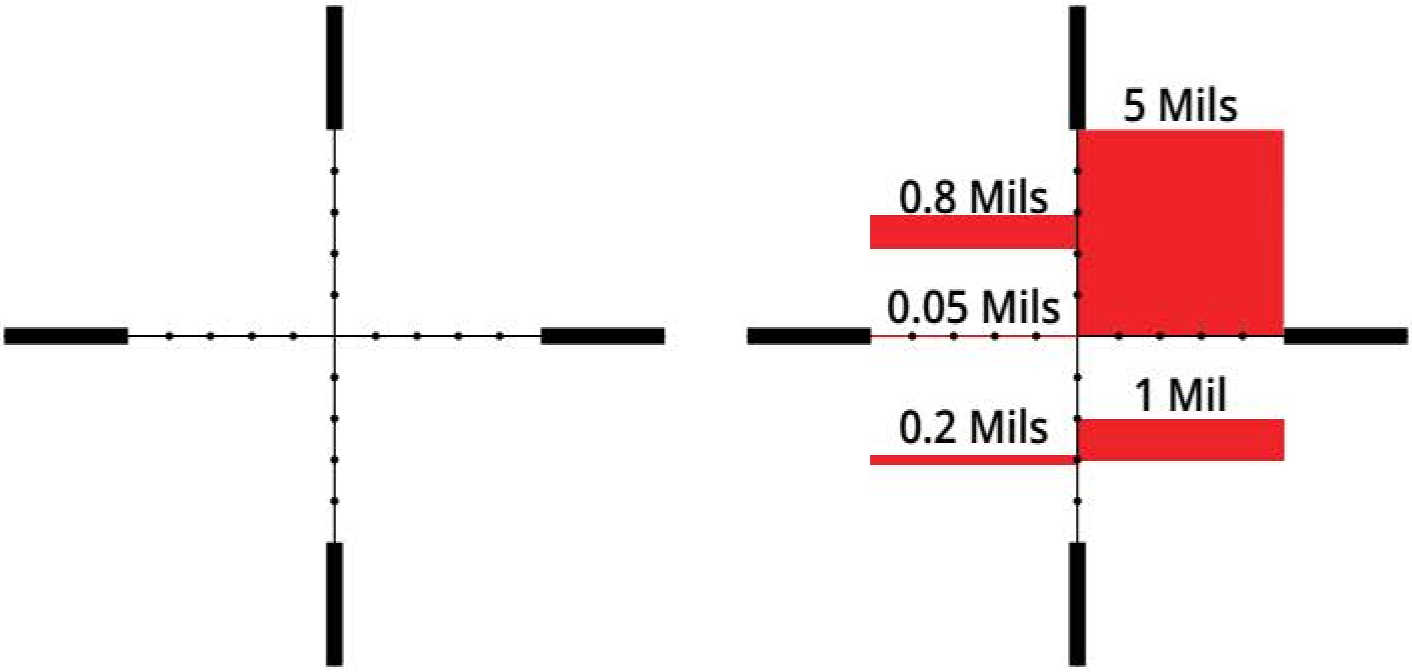


Image 115: A mil-dot reticle contains one vertical and one horizontal crosshair, with a set of dots atop them. The center of the dots are always 1 mil apart. Depending on the manufacturer, the diameter of the dots may be 0.2 or 0.25 mils. In this example, the dots are 0.2 mils in diameter, and therefore the space between the dots is 0.8 mils. The width of the crosshairs themselves can also be used as a very fine measure, although the crosshair width is often not given.

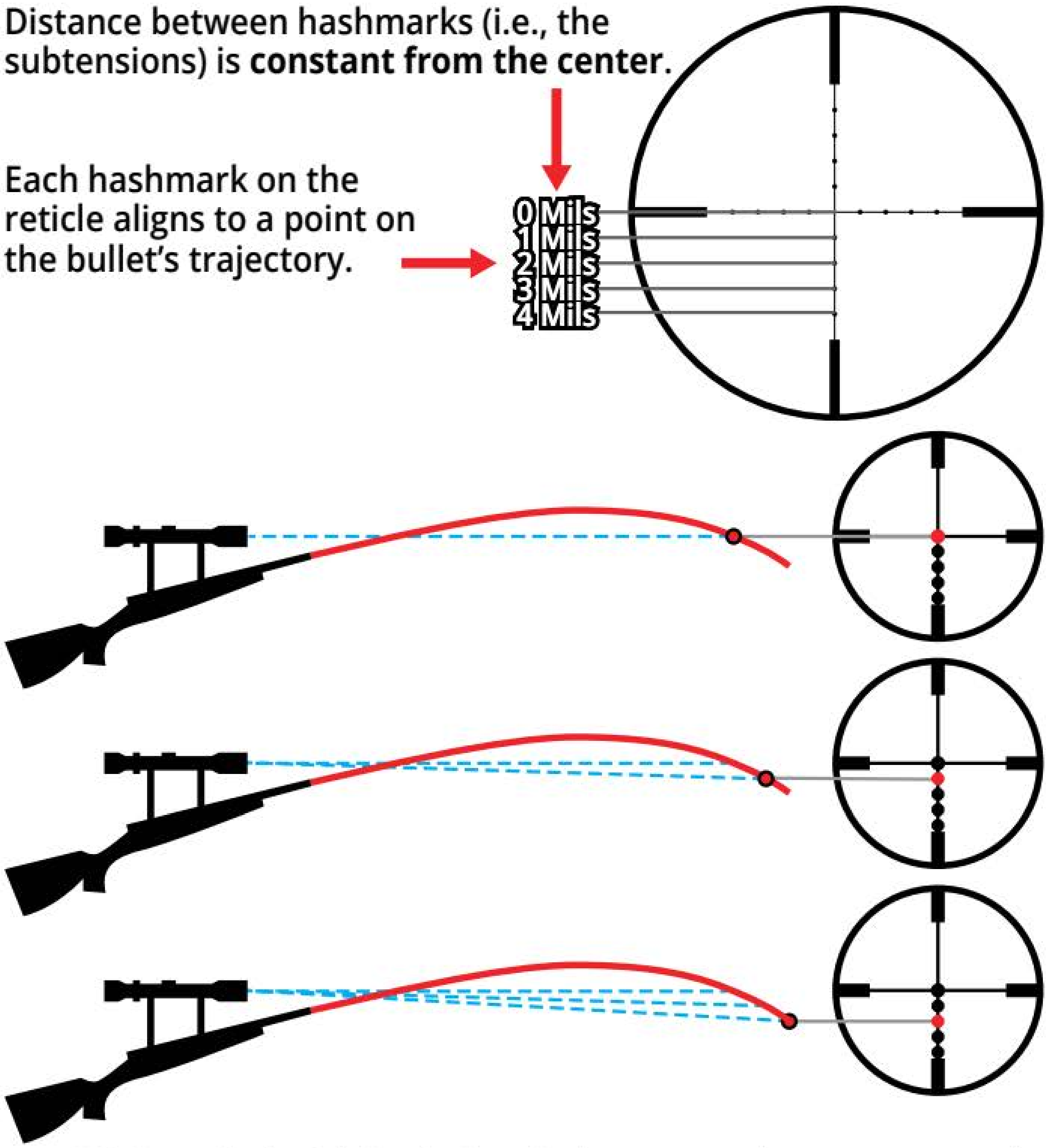
to the Earth and so a bullet fired farther has a lower impact in a scope's sight picture (past its second zero point). (See Image 116, Pg. 134.)

Therefore, predicting **a lower impact requires using a lower point-of-aim (i.e., a lower reference point or hashmark)**. This divergence between where the zeroed center of the reticle points (i.e., the zero point) and the actual point-of-impact is called "bullet-drop" (i.e., the linear distance on the target that a bullet drops from the zeroed point-of-aim).

Standard reticles, including the mil-dot reticle, measure angular distance and so require the extra step of converting the linear distance of bullet-drop to a mil or MOA measurement. (See Zeroing, Pg. 79.) Marksmen often use calculators or data cards to minimize mistakes. (See Conversion Charts, Pg. 222.)

One of the most basic and classic systems of reticle hashmarks can be seen on the mil-dot reticle. (See Image 115, Pg. 133.) It consists of a series of evenly spaced dots overlaid along both crosshairs. The vertical dots account for bullet-drop, and the horizontal dots account for crosswind, which pushes bullets sideways. (See Crosswind Deflection, Pg. 162.) Both series of dots can also be used for milling. (See Using a Standard Reticle (Milling), Pg. 112.) The distance between the centers of two adjacent dots is 1 mil, hence the name "mil-dot." Depending on the manufacturer, each dot is either 0.25 mils

Standard Reticle



Distance between hashmarks (i.e., the subtensions) is **constant from the center**.

Each hashmark on the reticle aligns to a point on the bullet's trajectory.

Image 116: A standard reticle has hashmarks that are spaced at a constant angular distance from the center. Lower hashmarks point to lower points on the bullet's trajectory, which are farther from the marksman. To find the distance (or the point on the trajectory) to which a hashmark points, a marksman measures that distance beforehand to create a conversion chart (See Image 120, Pg. 139.), or they predict the distance with a ballistic calculator (See Ballistic Calculators, Pg. 221.).

in diameter and spaced 0.75 mils apart or 0.2 mils in diameter and spaced 0.8 mils apart. These distances can be subtracted and added for more specific measurements. Manufacturers also produce tactical mil-dot reticles that use precise hashmarks instead of dots.

Proponents of the mil-dot reticle value its clean and less cluttered sight picture. However, since mil-dot reticles only have one horizontal line and

Grid Reticles

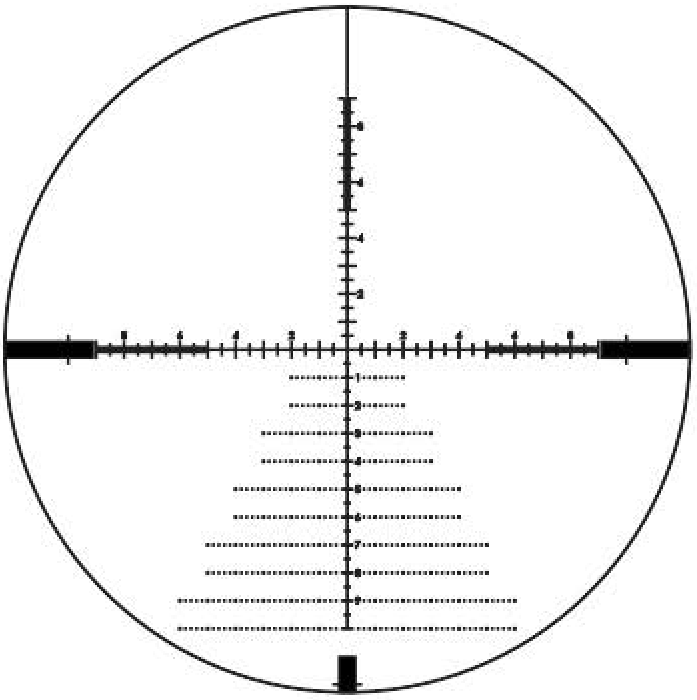


Image 117: Grid reticles have additional hashmarks in the bottom half to enable simultaneous holding for elevation and windage.

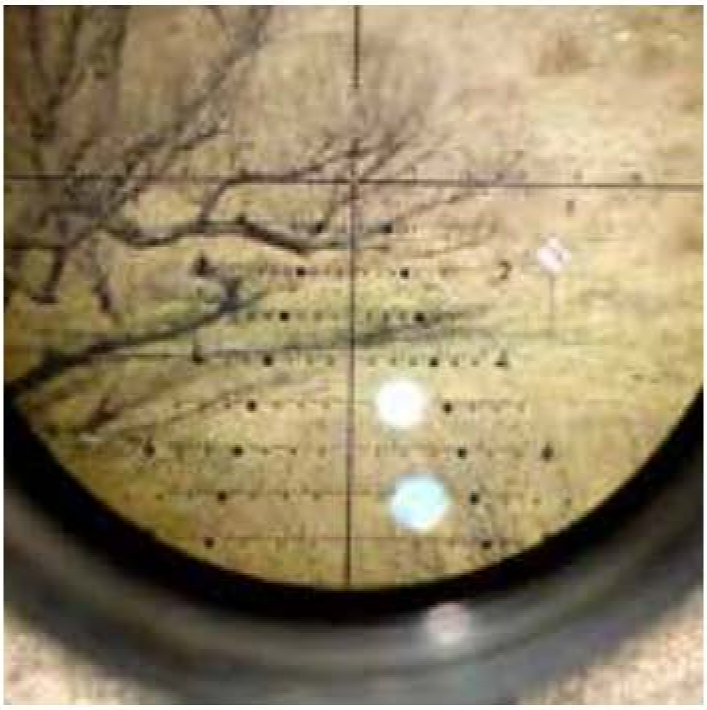


Image 118: Wind-dot reticles have hashmarks that form an upsidedown parabola-like shape emanating from the center of the reticle.

one vertical line, marksmen cannot precisely adjust for wind (horizontal movement) and bullet-drop (vertical movement) at the same time. Although more complex reticles may seem difficult to use at first, once mastered, they become fast, accurate, and reliable.

The most common reticles that are more complex than mil-dot reticles use a grid design, with hashmarks that allow for simultaneous adjustments for both wind and bullet-drop. Many gridded reticles consist of a pure grid, with dots and lines conforming exactly to a horizontal and vertical grid. (See Image 117, Pg. 135.)

Wind-dot reticles have additional windage markings, often dots, which do not measure angular distance per se, but rather the effect of the wind on a bullet. The effect of a constant crosswind (e.g., 10 km/h or mi/h) increases with distance. The farther a bullet travels to a target, the more wind is able to push it to the left or right. Therefore, the windage markings on lower rows are spaced farther apart to account for the fact that bullets traveling farther are also more affected by the same wind.

That being said, as bullets travel farther, they drop faster and so have less time to be affected by wind per unit distance fallen. In other words, the relationship between bullet-drop and a constant wind effect is not linear; for example, a bullet that drops 1 mil may be pushed by wind 1 mil to the right, but if the same bullet drops 3 mils, the same wind may push the bullet only

2.5 mils to the right. Therefore, wind dots form an upsidedown parabola-like shape emanating from the center of the reticle. (See Image 118, Pg. 135.)

Because both grid reticles and wind-dot reticles have more hashmarks at the bottom than at the center, they are sometimes called "christmas-tree reticles" because the pyramid shape with dots resembles a pine tree with ornaments.

13.d First and Second Focal Plane Reticles

A scope contains many lenses in a row to redirect light. Two of the lenses are focal-plane lenses. These lenses are locations within the scope where the image of the object or target is brought into focus, and they are also where a reticle (crosshairs or aiming point) is typically placed. (See Image 16, Pg. 35.) If the reticle is located on the focal-plane lens closer to the target (i.e., the first-focal-plane lens), the reticle changes size as the magnification is adjusted. Conversely, if the image is placed on the focal-plane lens closer to the marksman (i.e., the second-focal-plane lens), the reticle does not change size with magnification. (See Image 119, Pg. 137.) This is because the magnification assembly is between the first and second focal planes.

13.e Elevation Hold and Dial

In the context of scopes, "elevation" refers to vertical angular distance in the scope. In contrast, "bullet-drop" refers to the vertical linear distance that a bullet falls on the target from the zero point (usually where the center of the reticle points). In other words, **elevation is how a marksman compensates for bullet-drop**. For example, consider a rifle that is zeroed at 100 m (109 yd). If at 500 meters (547 yd) a bullet impacts 1 m (1.1 yd) lower on a target and 2 mils lower in the sight picture, then the marksman would have to adjust up the scope's reticle (i.e., increase elevation) by 2 mils to realign the point-of-aim with the point-of-impact.

"**Hold**" refers to using a hashmark on the reticle that is below the zero point as a point-of-aim. That is, the marksman physically holds up the reticle. For example, if a bullet drops by 5 mils at a certain distance, the marksman can hold their reticle 5 mils higher. That 5 mils would be the "elevation hold" for that distance.

To determine the correct elevation hold for a particular distance, modern marksmen rely on ballistic calculators. (See Ballistic Calculators, Pg. 221.) These devices, once set up according to the manufacturer's instructions, require

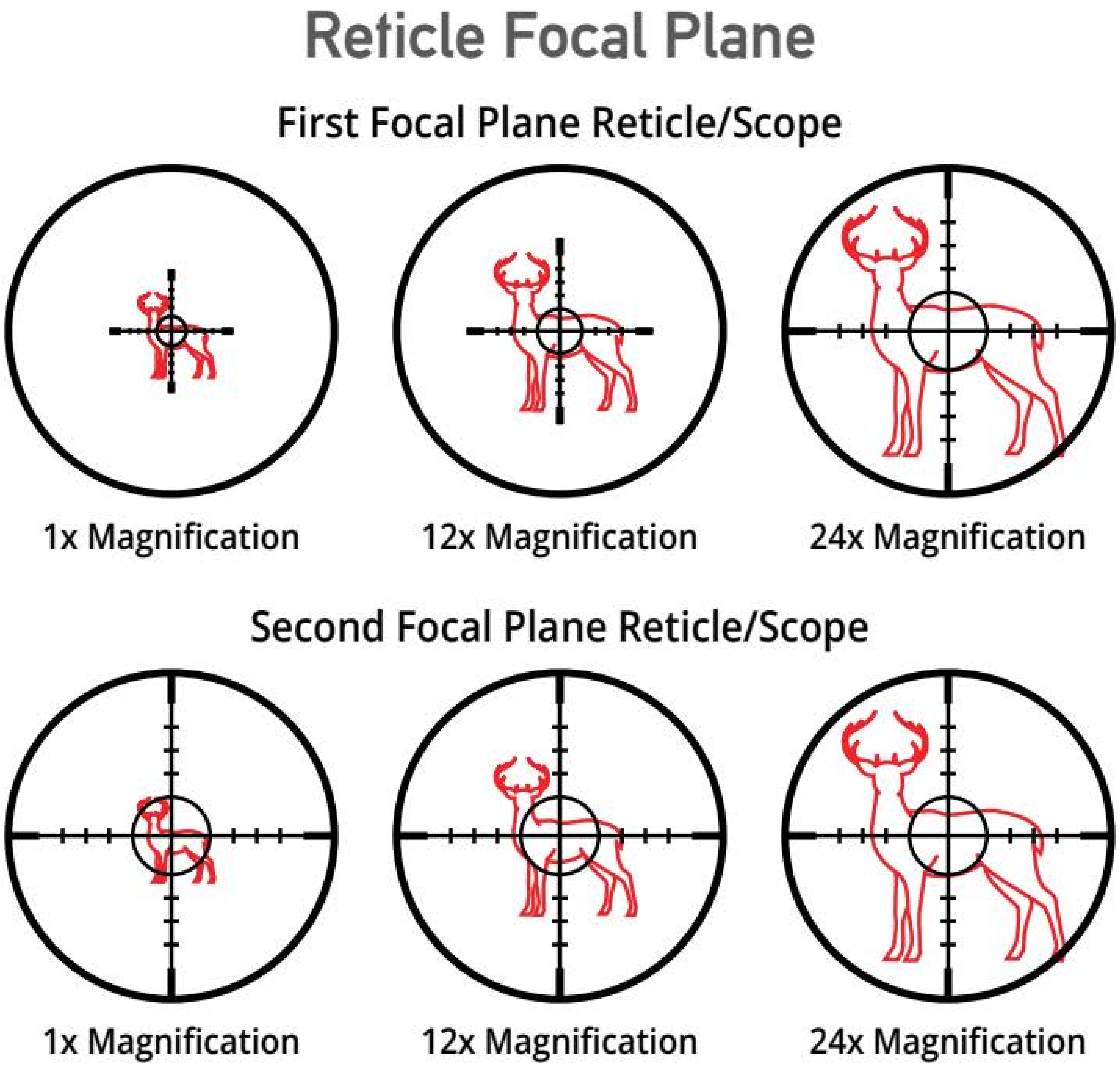

Reticle Focal Plane
First Focal Plane Reticle/Scope
1x Magnification
12x Magnification
24x Magnification
Second Focal Plane Reticle/Scope
1x Magnification
12x Magnification
24x Magnification

Image 119: Reticles can respond in one of two ways to magnification. If the reticle is placed in the front of the scope (i.e., "first focal plane" (FFP)), then it changes size when the sight picture is magnified. (See Image 16, Pg. 35.) The hashmark measurements in first-focal-plane scopes always stay constant, so for example, a 1-mil subtension is always 1 mil at any magnification. In contrast, when the reticle is placed in the rear of the scope (i.e., "second focal plane" (SFP)) the reticle is always the same size no matter the magnification. For a second focal plane scope, subtensions are only accurate at maximum magnification; however, this is rarely a problem since most marksmen only use an elevation hold at the maximum magnification (or half-max where subtension numbers are doubled) on a second-focal-plane scope.

marksmen to input into the calculator: the target distance, and various other information such as temperature, altitude, and type of equipment. Then the calculator outputs an elevation hold for the marksman to use. Many ballistic calculators are available online for free. Others come in standalone devices.

Using ballistic calculators is a vast improvement over the traditional method, which was trial-and-error. To determine accurate holds, a traditional marksman would have set up targets at various distances, shoot at them, and measure the bullet-drop at each distance. The marksman would then record each drop in a log book for future reference, called the "Data-On-Previous-Engagements" (DOPE) book. (See Recording, Pg. 217.) DOPE books are not limited to bullet-drop data, and may contain other valuable information on every relevant variable (e.g., air temperature and wind effects).

After collecting all their data, the marksman would plot each bullet-drop measurement against the corresponding shooting distance. Such a graph can help to understand how bullet-drop changes with different target distances. So for example, if a bullet had previously dropped 5 mils at 500 m (547 yd), a marksman could reasonably assume that future bullets would exhibit a similar drop. And if a marksman needed to shoot at 450 m (492 yd) but only had bullet-drop information for 400 m (437 yd) and 500 m (547 yd), they could calculate the average between these two distances.

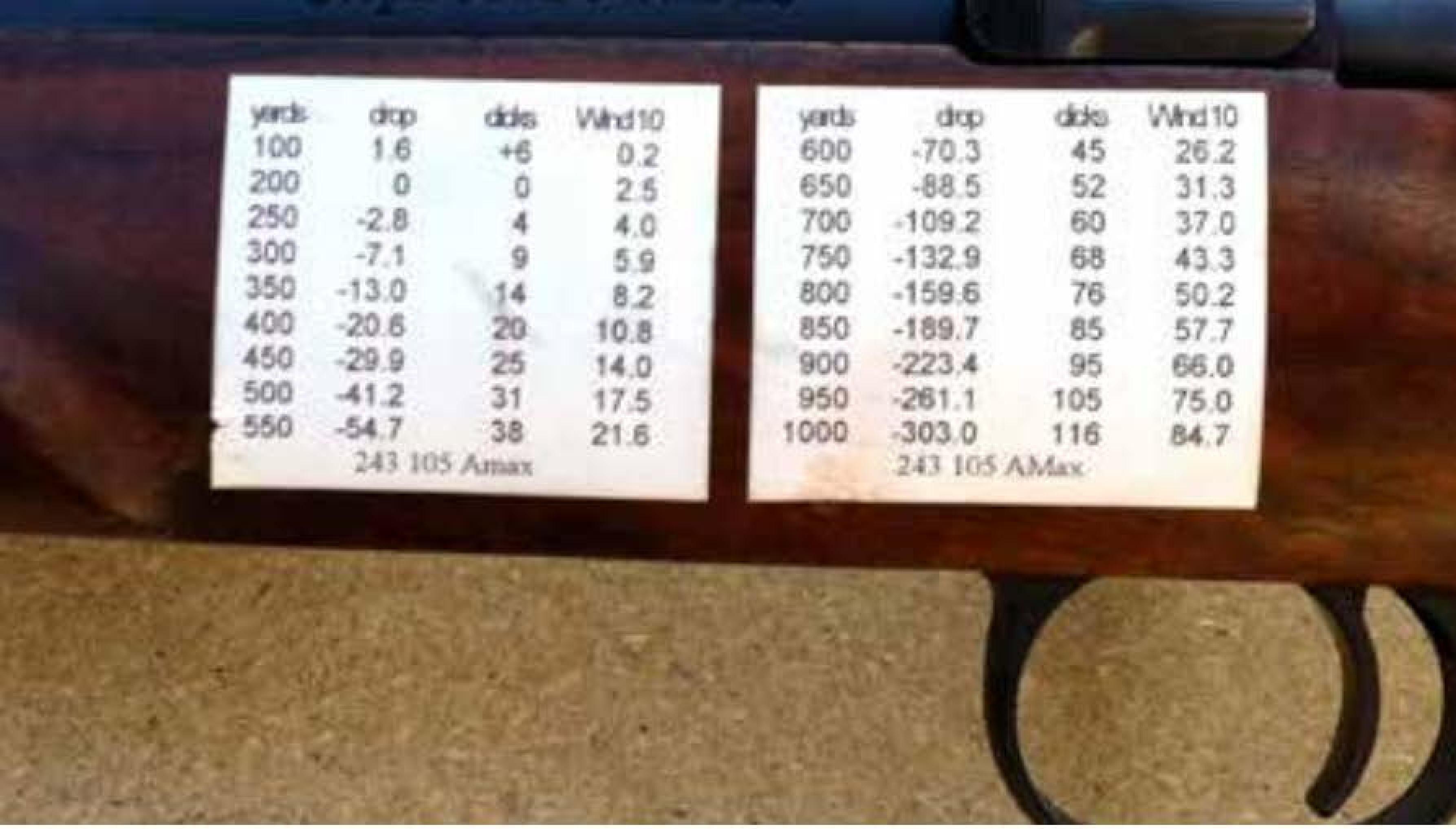
Instead of holding the reticle up, another option is **dialing** the elevation turret and adjusting it to realign the zeroed point with the desired point-of-impact. For example, if a bullet drops by 5 mils, the marksman can rotate the elevation turret to raise the reticle within the scope by 5 mils ("elevation dial").

This approach eliminates the need to rely on vertical hashmarks, meaning a marksman can always aim with the center of their reticle. Some marksmen choose this method because basic reticles only offer windage adjustments on the baseline (e.g., the mil-dot reticle). (See Image 120, Pg. 139.)

However, when shooting at distances where both wind and bullet-drop affect a bullet's trajectory, it is advisable to upgrade to a modern reticle with a grid pattern of horizontal and vertical hashmarks. (See Image 117, Pg. 135.) This is because dialing for elevation: takes more time than holding; diverts a marksman's attention from the sight picture more; and a marksman may forget to reset the elevation turret when a new target appears.

That being said, there are optional scope features for both holders and dialers. Holders prefer scopes that feature lockable turrets. Dialers prefer scopes with zero stops and tactile rotation indicators to allow for precise dial adjustments without looking at the turrets.

If a marksman does choose to dial their turrets for each shot, it is crucial that they consistently start and end with a zero elevation and windage setting to develop reliable habits. Additionally, for rapid firing, marksmen must learn to adjust the turrets while only glancing at turrets briefly to verify their accuracy or even adjusting them without looking at them at all.



yards	drop	clicks	Wind 10
100	1.6	+6	0.2
200	0	0	2.5
250	-2.8	4	4.0
300	-7.1	9	5.9
350	-13.0	14	8.2
400	-20.6	20	10.8
450	-29.9	25	14.0
500	-41.2	31	17.5
550	-54.7	38	21.6

243 105 Amax

yards	drop	clicks	Wind 10
600	-70.3	45	26.2
650	-88.5	52	31.3
700	-109.2	60	37.0
750	-132.9	68	43.3
800	-159.6	76	50.2
850	-189.7	85	57.7
900	-223.4	95	66.0
950	-261.1	105	75.0
1000	-303.0	116	84.7

243 105 AMax

Image 120: This marksman has attached to his rifle a table that compares target distance to the marksman (yards) against 1) bullet-drop (inches), 2) dial rotation to compensate for the drop (clicks), and the wind deflection from a 10 mi/h crosswind (inches). The scope is a 1/4 MOA scope, so each click corresponds to a rotation of the reticle by 1/4 MOA. At 1000 yd, 1 MOA is 10.47 in, so at 1000 yd, each click corresponds to 2.62 in. Because windage was not also converted to clicks, it can be presumed that this marksman dials for distance but holds for wind.

13.f Precisely Adjusting the Sight Picture

At long distances, even tiny movements of the scope can have outsized effects on the accuracy of a rifle; therefore, precise adjustment is paramount. To precisely move a rifle requires very fine and controlled movements by the marksman. Movements must also be done quickly so a marksman can both avoid fatigue and also hit time-limited targets.

An advanced technique for precisely adjusting elevation hold involves placing a sandsock under the rifle's buttstock. (See Image 17, Pg. 37.) A sandsock is a small, durable bag filled with sand, plastic beads, or other granular material. Then the marksman uses their support hand to hold the sandsock in position. (See Image 121, Pg. 141.)

By squeezing the sandsock, it elongates and pushes the rifle's buttstock up, causing the entire rifle (including the reticle) to rotate. As the buttstock goes up, the muzzle goes down. This causes the reticle to point lower. On the other hand, relaxing the squeeze lowers the sandsock and rotates the rifle in the opposite direction; the buttstock goes down and consequently, the muzzle goes up. This causes the reticle to point higher.

Because the support hand is no longer supporting the front of the rifle but is positioned at the marksman's chest, this technique requires excellent front support. This often means being in the prone position and with the assistance of a bipod. The support hand must then be able to stabilize both the sandbag and the rifle together, and the marksman must be careful not to unintentionally move the rifle when operating the bolt of the weapon.

Using a sandsock is helpful but not strictly necessary. A skilled marksman can squeeze their fist below the stock, effectively achieving the same sandsock effect. However, when only using their hand, it is important for marksmen to avoid accidentally squeezing their support hand when pulling the trigger, as that would disrupt the point-of-aim at a critical moment.

13.g Bullet-Drop Compensator Reticles

Similar to the mil-dot reticle, the bullet-drop compensator (BDC) reticle features a horizontal and vertical line. However, the BDC reticle differs in that the hashmarks are placed to correspond to points in the bullet's trajectory that are evenly spaced distances from the marksman, rather than correspond to fixed angular intervals like the mil-dot does. (See Image 122, Pg. 142.)

For example, a 100-m (109-yd) BDC reticle has a hashmark for each 100 m distance to the target. If the center point-of-aim is zeroed at 100 m, the first hashmark below center predicts the impact at 200 m (219 yd), the second hashmark below center at 300 m (328 yd), and so on. Some BDC reticles have labels on the reticle denoting the distance to the target for each hashmark.

Subtensions (the spacing of the hashmarks) on the BDC reticle increase exponentially down the vertical crosshair to account for the increasing drop that bullets experience as they travel further from the marksman.

BDC reticles are efficient because they work directly with rangefinders, using linear distance as input. For example, suppose a rangefinder indicates a target is at 300 m (328 yd). In this case, a marksman can immediately aim with the second hashmark (assuming the center point is zeroed at 100 m (109 yd) and assuming each additional 100 m of distance represented by one hashmark downward). This contrasts with the standard angular-distance reticles which require the extra step of converting linear distance to the target into a mil or MOA measurement on the reticle.

Using Sandsock to Adjust Sight Picture

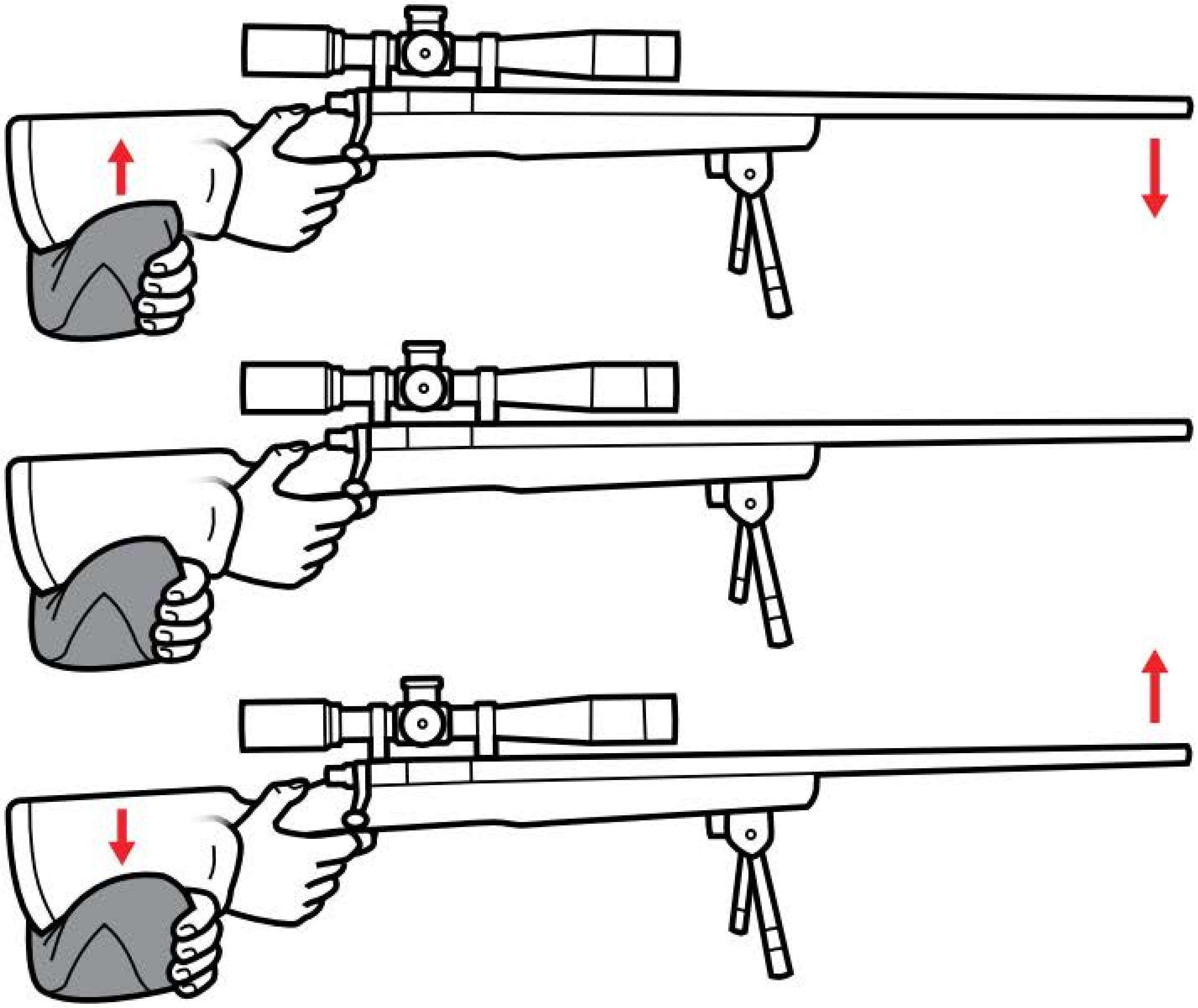


Image 121: In the center is a neutral-position sandsock under the buttstock of the rifle. (See Image 17, Pg. 37.) **Squeezing the sandsock** (top) rotates the front of the rifle down. Relaxing the sandsock (bottom) rotates the front of the rifle up.

There are three issues with BDC reticles. First, the bottom half of the reticle cannot be used for milling to estimate the distance to a target. (See Using a Standard Reticle (Milling), Pg. 112.) To solve this, many BDC reticles have standard hashmarks in their upper half; or marksmen can use the horizontal hashmarks on the reticle.

Second, the location of each BDC hashmark depends on the specific rifle and ammunition being used. That is, faster ammunition would hit higher on a target than a BDC would predict, and slower ammunition would hit lower. For example, if a marksman switches to more powerful, faster ammunition, each dot may represent impacts at 103, 211, and 336 m (respectively 113, 231, and 367 yd), instead of a perfect progression of 100, 200, and 300 m (respectively 109, 219, and 328 yd).

Bullet-Drop Compensator Reticle

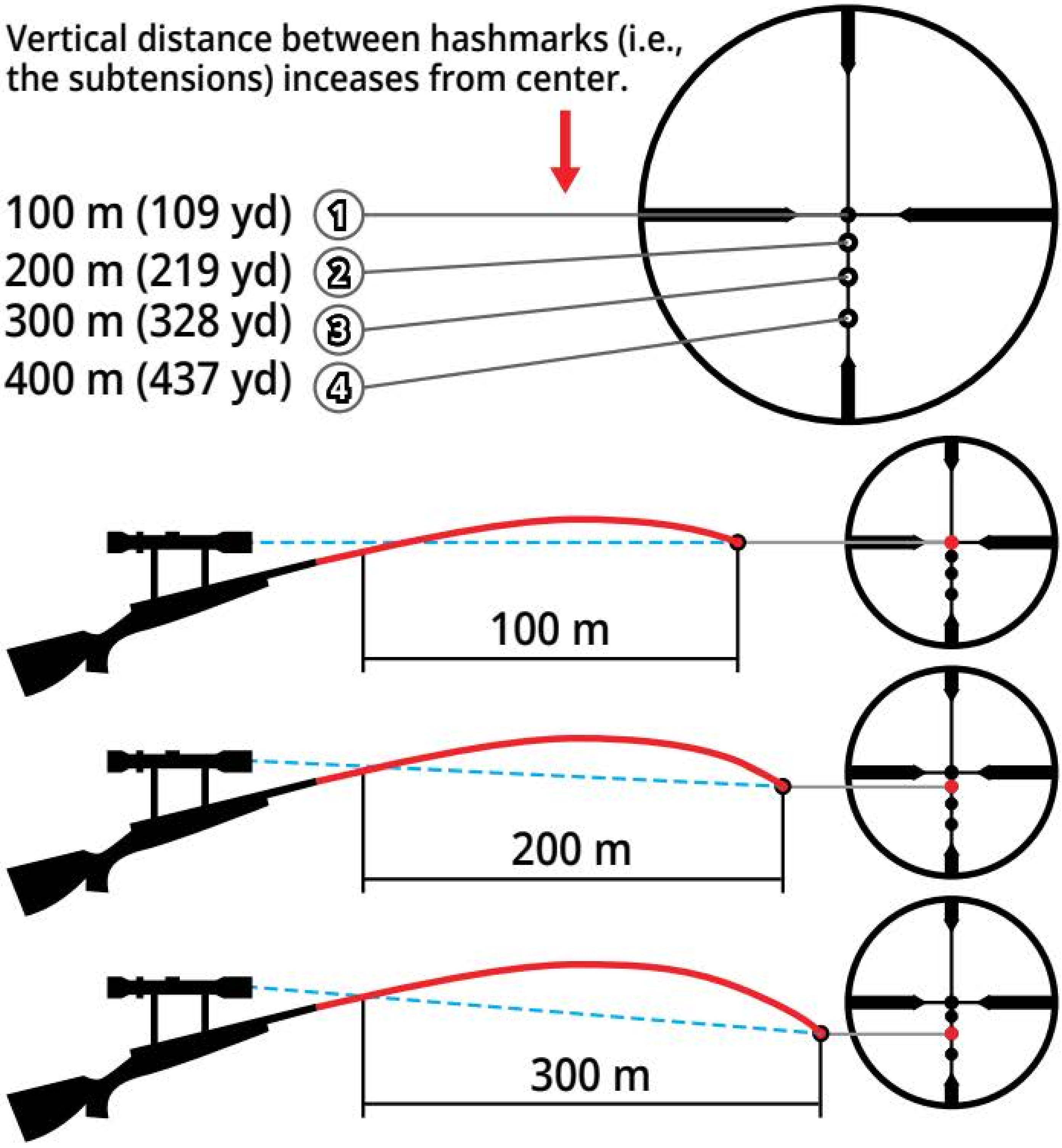

Vertical distance between hashmarks (i.e., the subtensions) inceases from center.
100 m (109 yd) ①
200 m (219 yd) ②
300 m (328 yd) ③
400 m (437 yd) ④
100 m
200 m
300 m

Image 122: A bullet-drop compensator (BDC) reticle has hashmarks that correspond to set intervals of distance from the marksman to the target. The hashmarks in this example (labeled 1, 2, 3, and 4) align to a point on the bullet's trajectory that is a specific distance (here 100 m) farther from the marksman than the previous one.

Bullet-drop compensators bypass the conversion of distance to mils, MOA, or clicks. (See Image 120, Pg. 139.) They are typically only **used for 500 m or yd and below** because they only work for a specific setup, and quickly lose accuracy in different environments. For example, while the second hashmark may correspond to 300 m for one setup, it could correspond to 343 m for another setup.

Finally, if the scope is a second-focal point scope, the BDC hashmarks only correctly measure at a single magnification setting, typically the highest. (See Image 119, Pg. 137.)

Since the BDC hashmarks may denote somewhat arbitrary distances and cannot account for individual weapon system variations, their intended purpose of simplifying the translation of distance to a hashmark is not fully achieved. This error compounds with distance, **making BDC reticles rarely used beyond 500 m** (547 yd).

13.h Danger Distance

Essentially, the danger distance is the base of a rectangle at a specific distance from the marksman. The height of the rectangle is delimited by an upper and lower offset from the point-of-aim chosen by the marksman. The bottom of the rectangle is the subset of the bullet's trajectory in which a bullet would hit a target within that defined height. (See Image 123, Pg. 145.)

For example, consider a target area (i.e., killzone) that is 10 cm (3.9 in) tall. The bullet may fall 10 cm (3.9 in) from 50 to 200 m (55 to 219 yd). That means that the target can be anywhere within that range and if the marksman aims at the center of the target area, the bullet would impact somewhere within the target area (although not necessarily the center of the target).

Put simply, a bullet always hits a target smaller than the killzone within the killzone's corresponding danger distance because the bullet never exceeds the killzone's bounds along the danger distance. If, for example, a bullet flies faster and flatter, its danger distance is longer because it can travel even farther without exceeding the bounds of the killzone. A marksman can achieve a flatter bullet trajectory through factors such as more powder, a longer barrel, or a bullet with a higher ballistic coefficient.

Calculating a danger distance is a useful technique to hit targets without calculating an elevation hold. Although uncommon among marksmen with modern scopes, knowing a danger distance is vital when using a scopes that lacks hashmarks on its reticle. Knowing the danger distance is also useful for marksmen who 1) know their target (e.g., a deer), but 2) do not know that target's exact distance, and 3) they do not want to fiddle with a rangefinder.

For example, a North American whitetail deer may have 20 cm (7.9 in) of vital organs below the vertical middle of their torso, behind their shoulder. Therefore, hunters use this 20 cm (7.9 in) killzone to determine a danger distance. For example, a marksman might zero their rifle to have the far-zero at 50 m (55 yd), meaning that after 50 m (55 yd), the bullet always drops lower. Then, the marksman might test the rifle and discover that the bullet drops to 20 cm (7.9 in) at 250 m (273 yd). Therefore, if the marksman aims behind the shoulder in the middle of the deer's ribcage anywhere within the danger distance of 50 to 250 m (55 to 273 yd), they are guaranteed to hit the vital organs and thereby secure a humane kill.

For a given target area (i.e., killzone), danger distance is usually derived from the distance to the target. However in reverse, the distance to the target can also be derived from the danger distance. This occurs when the distance to the target is unknown, and the marksman must determine their allowable margin of error when estimating that distance. For example, if a target is actually 500 m (547 yd) away and 25 cm (9.8 in) tall, and the bullet drops 25 cm (9.8 in) from 475 to 525 m (520 to 574 yd), then the marksman's estimate of the target's distance can be anywhere within that 475 to 525 m (520 to 574 yd) range and they would still hit the target if they aim at its center. In summary, knowing the danger distance is 50 m (55 yd) at 500 m (547 yd) for a 25 cm (9.8 in) target lets the marksman know that they have a 5% margin-of-error in their distance-to-target estimate at 500 m (547 yd) for a 25 cm (9.8 in) target. (See Image 107, Pg. 124.)

A specific case of danger distance is the point-blank distance, which is the danger distance starting from the muzzle for a given target height. Since a bullet momentarily travels above the sightline of a scope during its trajectory, the top of the killzone for the point-blank distance must be higher than the point-of-aim. For example, the maximum trajectory of a bullet may be two cm (0.79 in) above the sightline. However, after reaching the maximum trajectory, the highest point never changes regardless of how much farther the bullet travels because it always begins to fall after that point. Point-blank distance is not particularly useful for long-range marksmen because, by definition, they do not shoot at point-blank range.

14. Eliminating Rifle Cant

"Cant" refers to an inclination or tilt in an object that deviates it from the "vertical" or "horizontal." For this book, "vertical" is the direction of gravity, and "horizontal" is perpendicular to gravity. Therefore for example, a canted scope is one that is not above the barrel with respect to gravity. It can also help to define a rifle according to the three anatomical planes (See Image 124, Pg. 146.):

Danger Distance and MPBR

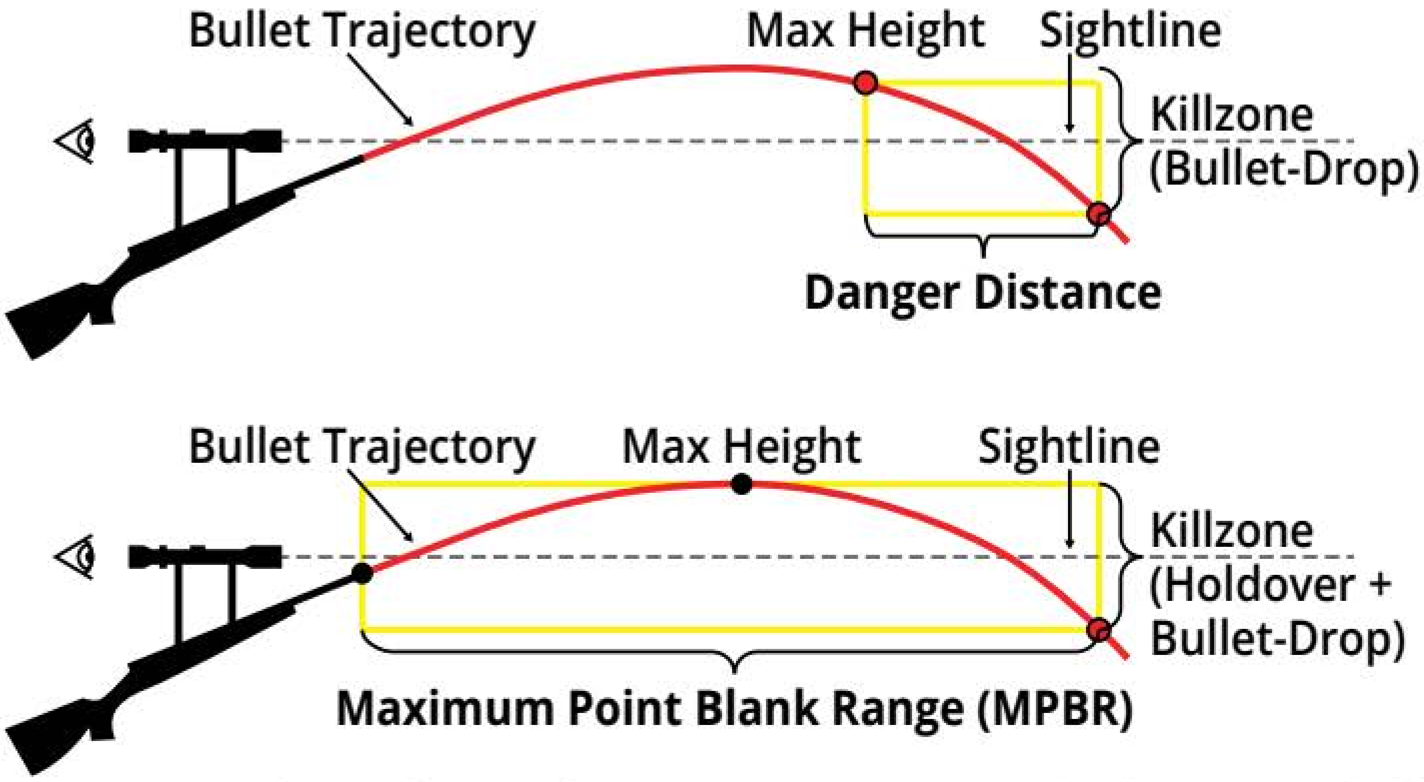


Image 123: A danger distance for any given trajectory is the distance in which a bullet **is present within a vertical range (i.e., the killzone)**. Together, the danger distance and the killzone form a rectangle, with the max height being one corner and the minimum height being the opposite corner. The maximum point blank range (MPBR) is **a special case of the danger distance** where the danger distance is defined as starting at the muzzle, instead of at an arbitrary point in the trajectory. The minimum height is still defined at whatever point the marksman wants to cover their desired target area.

Median (Sagittal Plane) – This plane divides the rifle into left and right sections. It helps describe the tilting of a rifle up or down (i.e., pitch rotation). Pitch rotation is how a marksman changes how far, or at what elevation, a rifle shoots.

Transverse (Horizontal Plane) – This plane divides the rifle into upper and lower sections. It helps describe side-to-side movements, such as swinging the rifle left or right (i.e., yaw rotation). Yaw rotation is how marksmen aim left and right, either at new targets or to account for wind.

Front (Coronal Plane) – This plane divides the rifle into front and back sections. It helps describe rotational movements, such as spinning the rifle along its long axis (i.e., roll rotation). Marksmen only roll-rotate their rifles when they have no other choice for whatever reason (e.g., a restricted loophole). Otherwise, any roll rotation is what is known as "**cant**."

Cant is bad because of how bullets exit a barrel. Barrels always point towards the sightline, which emanates straight out of the scope. When a rifle has

Anatomical Planes

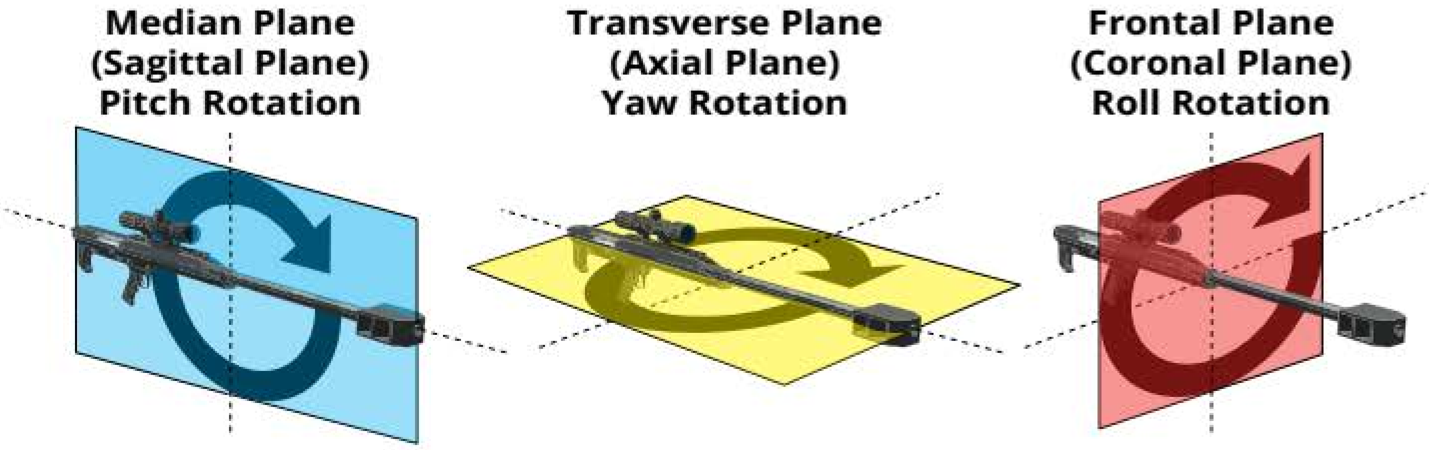
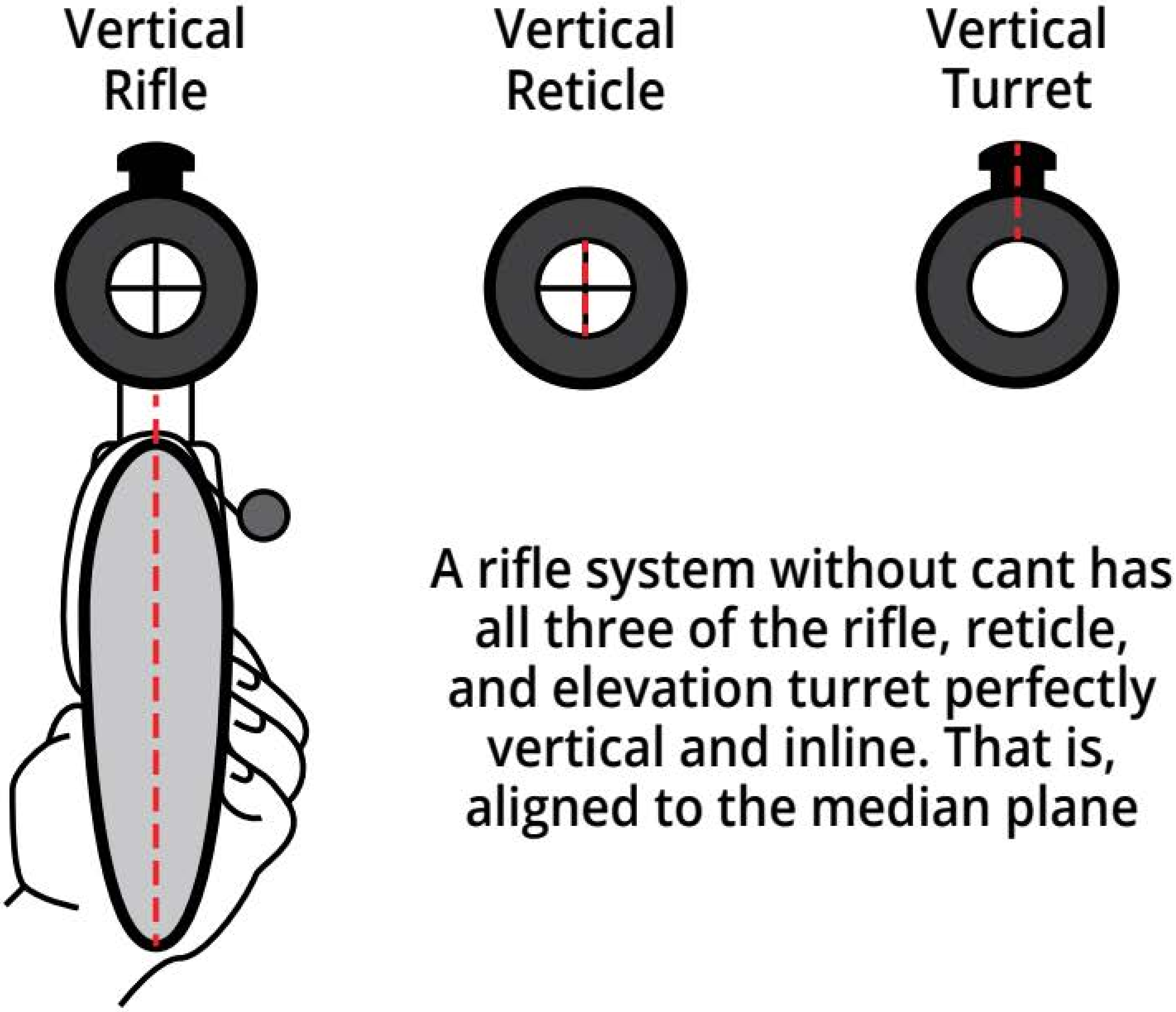

Median Plane
(Sagittal Plane)
Pitch Rotation
Transverse Plane
(Axial Plane)
Yaw Rotation
Frontal Plane
(Coronal Plane)
Roll Rotation

Image 124: There are **three anatomical planes**, each of which corresponds to a dimension of rotation. A rifle is oriented perfectly vertical in the median plane. It is rotated in the median plane to shoot at closer or nearer targets. A rifle is rotated in the transverse plane to aim to the left or right. **A rifle is never rotated in the frontal plane. To do so introduces cant.**

Rifle System Alignment


Vertical
Rifle
Vertical
Reticle
Vertical
Turret

A rifle system without cant has all three of the rifle, reticle, and elevation turret perfectly vertical and inline. That is, aligned to the median plane

Image 125: A perfectly aligned rifle is vertical and centered on the **median plane**.

no cant, bullets exit the barrel going slightly up to meet the sightline; but when cant is present, bullets must go slightly to the left or right to meet the sightline. A bullet then keeps that sideways moment when falling as well. **That is, cant forces a bullet to travel sideways a bit.**

Therefore, shooting with a cant is difficult for two reasons. First, rifles are zeroed without cant, and so introducing it deviates a bullet from its zero. That is, it is far easier to keep a rifle vertically upright as opposed to rotated by an arbitrary amount. Second, the sideways deviation from cant increases linearly with the distance the bullet travels (i.e., bullets shot farther deviate more). Zero cant is far easier to deal with because zero always “scales” to zero.

14.a Formulas for Cant Offset

Marksmen must attempt to eliminate cant, so calculating the amount of cant offset is almost never useful. That being said, the offset between where a bullet would impact from a rifle in a proper orientation versus a canted orientation is presented here for completeness and is determined by the following:

Variables:

Velocity towards the scope *(v towards scope)* – The component of a bullet’s muzzle velocity that directs the bullet towards the scope (as opposed to forward). For a non-canted rifle, this would be the vertical component of the bullet’s muzzle velocity.

Cant offset occurs because bullets are not fired straight; they are fired slightly upwards so that the trajectory of the bullet can meet the sightline. When a rifle is canted, some of this normally vertical velocity is converted into sideways velocity.

Bullet travel time *(travel time)* – The amount of time the bullet takes to hit the target in seconds. Because velocity is distance per unit of time, knowing the velocity and time allows a marksman to calculate distance, or in this case, the cant offset.

Horizontal Offset *(Ox)* – The horizontal change in distance from a bullet impact from a vertical rifle compared to that of a canted rifle.

Vertical Offset *(Oy)* – The vertical change in distance from a bullet impact from a vertical rifle compared to that of a canted rifle.

θ – The cant angle, where 0 is perfectly vertical.

Sin and Cos – Abbreviations for “sine” and “cosine” respectively, trigonometric functions that translate a degree to a percent. (See Image 178, Pg. 210.)

Formulas:

- $\text{Horizontal Offset (Ox)} = (v \text{ towards scope}) \times (\text{travel time}) \times \sin(\theta)$
- $\text{Vertical Offset (Oy)} = (v \text{ towards scope}) \times (\text{travel time}) \times (\cos(\theta) - 1)$

Examples:

If $\theta = 0°$, then:

- The rifle is vertically upright.
- Both $\sin(\theta) = 0$ and $(\cos(\theta) - 1) = 0$, so there are no offsets.

If $\theta = 90°$ or $270°$, then:

- The rifle is sideways.
- $\sin(\theta) = 1$, so all of the energy that pushes the bullet up towards the scope now pushes the bullet sideways towards the scope.
- $(\cos(\theta) - 1) = -1$, so the bullet never rises because it is fired perpendicular to gravity. Because the presence of an upwards velocity is set to "0" (i.e., $\cos(90°) = 0$), the "-1" indicates the bullet would fall below that baseline.

If $\theta = 180°$, then:

- The rifle is upsidedown.
- $\sin(\theta) = 0$, so there is no vertical offset.
- $(\cos(\theta) - 1) = -2$, so the bullet not only lacks the energy of being pushed up, but is actively fired at a downwards angle towards the scope.

Conclusions:

- Because *(v towards scope)* and *(travel time)* are both constant for a given muzzle velocity and distance to target, for any particular setup the horizontal and vertical offsets are only determined by the cant angle. Because the cant angle is input into sine and cosine formulas, **canting a rifle makes bullets follow a circle** (i.e., the cant offset circle), where the zero point is the apex of that circle. (See Image 127, Pg. 151.)
- At the zero distance, "*(v towards scope)* × *(travel time)*" is calibrated to be exactly equal to the bullet-drop at that distance. Therefore, the radii of the boreline circle (i.e., where the boreline points as a rifle is rotated around the sightline) and the canting error circle are both exactly equal to the vertical travel of the bullet. A side effect is that, at the zero distance, cant is unaffected by whether a scope is mounted high or low on a rifle.
- Generally, beyond the zero distance, a low-mounted scope gives less canting error, while before the zero distance, a high-mounted scope gives less canting error.

- *(v towards scope)* can be deduced from other variables: *(v towards scope)* = *(Ox)* / *(travel time)* where a rifle shot at 90° (sideways), so that sin(θ) = sin(90°) = 1. That is, fire a zeroed rifle at 90° at its zero distance. Then measure the *(Ox)* on the target and measure *(travel time)* using a chronometer to measure the muzzle velocity. Divide *(Ox)* by *(travel time)* to find *(v towards scope)*.
- Close to 0, sine changes much more quickly than cosine. For example, at 1°, sin(1°) = 1.75% which is 116 times (1 - cos(1°)) = 0.015%. At 5°, sin(5°) = 8.72% which is 51 times (1 - cos(5°)) = 0.172%. This means that the vertical component of cant is almost always negligible for most marksmen. In contrast, the horizontal component can be a significant cause of a bullet's deviation to the left or right.

  For example, if a bullet is fired with a muzzle velocity of 1000 m per second, it would take 0.1 s to reach a target 100 m away. Assuming the scope is mounted 5 cm above the bore, and the rifle is zeroed to reach the sightline and fall again on its way to the 100 m zero point, the bullet travels towards the scope line at a rate of 10 cm per 0.1 s, or 1 m/s at the muzzle. If the bullet slows down as it travels to a target at 1000 m away, it may have a travel time of 2 s. Using the horizontal offset formula, 1 m/s × 2 s × 1.75% = 3.5 cm or 1.4 in of horizontal offset for 1°of cant.

14.b Holding Cant

Holding cant is the simplest type of cant. This occurs when a marksman rolls their weapon simply because they are handling it wrong. Holding cant is not due to a mismeasurement, misalignment, nor a miscalibration; rather the marksman is simply rotating their rifle.

Rotation can happen, for example, with new marksmen who may naturally hold their rifle with a cant. This often happens because they have weak or untrained neck muscles, causing them to lean the rifle toward their cheek to achieve a comfortable cheek weld. On the other hand, excessive pressure on the cheek weld can cause a marksman to push the rifle away from them, thereby canting it in the opposite direction.

During teaching and zeroing, one way to identify these patterns is with the assistance of an observer who can correct improper posture. Observing shot groups can also indicate whether the rifle is canted. When the marksman cants the rifle towards their head (for right-handed marksmen), shots tend to be to the left, while for left-handed marksmen, shots tend to be to the right.

Effect of Cant Side View

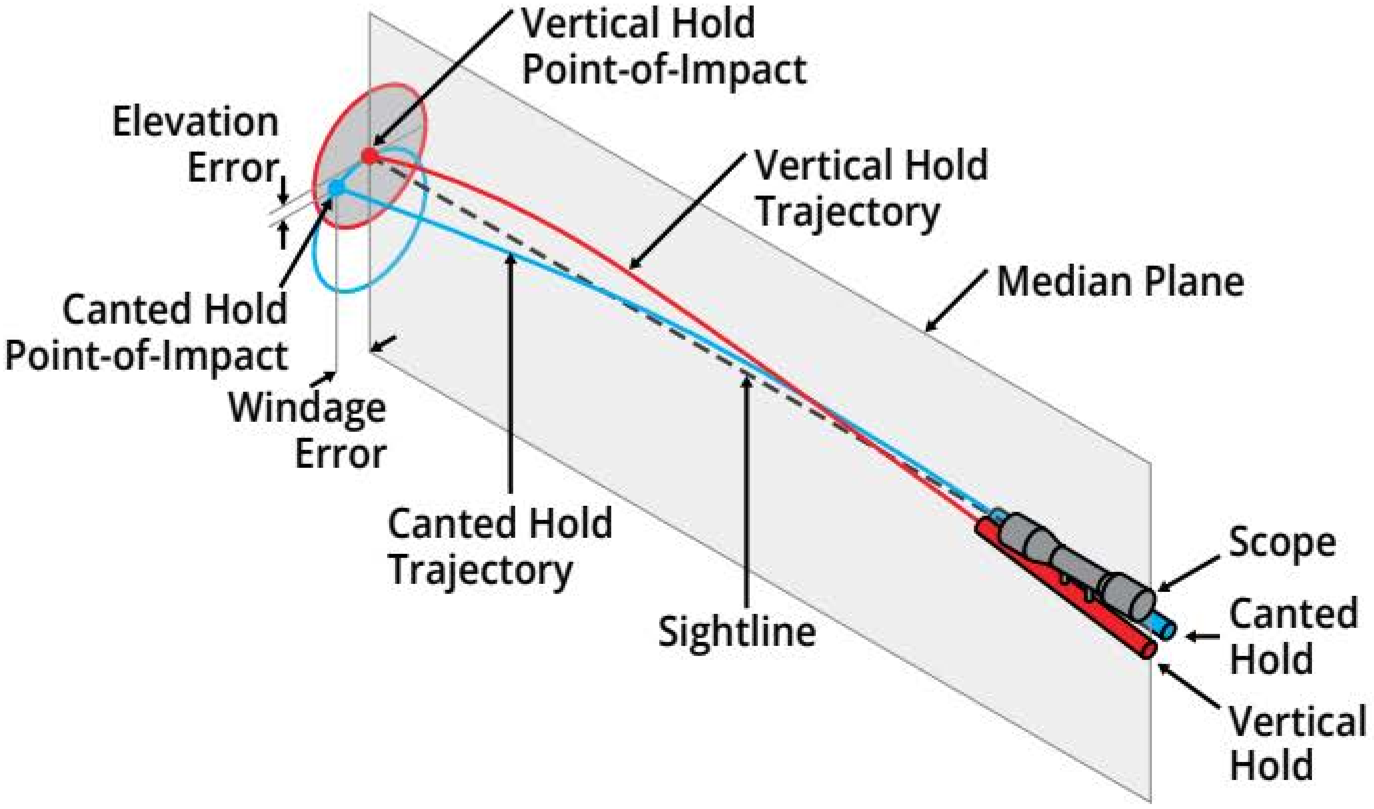


Image 126: This diagram shows a rifle that is firing at the zero distance, where the vertical-hold point-of-aim impacts at the far-zero. (See Image 112, Pg. 129.) Canting a rifle makes bullets impact lower and to the side. The vertical difference between the vertical-hold point-of-impact and the canted-hold point-of-impact is the "**elevation error**." The horizontal difference between the vertical-hold point-of-impact and the canted-hold point-of-impact is the "**windage error**."

Rifle canting can be prevented before it occurs by **checking the orientation of the rifle before shooting**. This is done with a bubble level attached to the rifle. (See Image 128, Pg. 153.) When the bubble is between the two interior lines, the rifle is level. When the rifle is canted to the left, the bubble moves outside the right line and vice versa. Using a level is particularly useful when shooting from uneven terrain that can disrupt a marksman's natural sense of balance by a few degrees.

However, a bubble level is not a precise tool for determining orientation, and with sufficient practice, marksmen may even become more accurate than a bubble level. Additionally, while marksmen can purchase highly accurate leveling attachments, no external level can be observed while also looking through the scope. As a result, some modern scopes now incorporate an internal level into the sight picture.

It is worth noting that cant is different from an offset-mounted scope. That is, some cross-dominant marksmen (e.g., left-eye-dominant, right-hand-dominant marksmen) intentionally offset their scope from the midline of their rifle to make their setup more comfortable. Despite the offset, these special setups still have the bullet exit the muzzle with zero side-to-side velocity

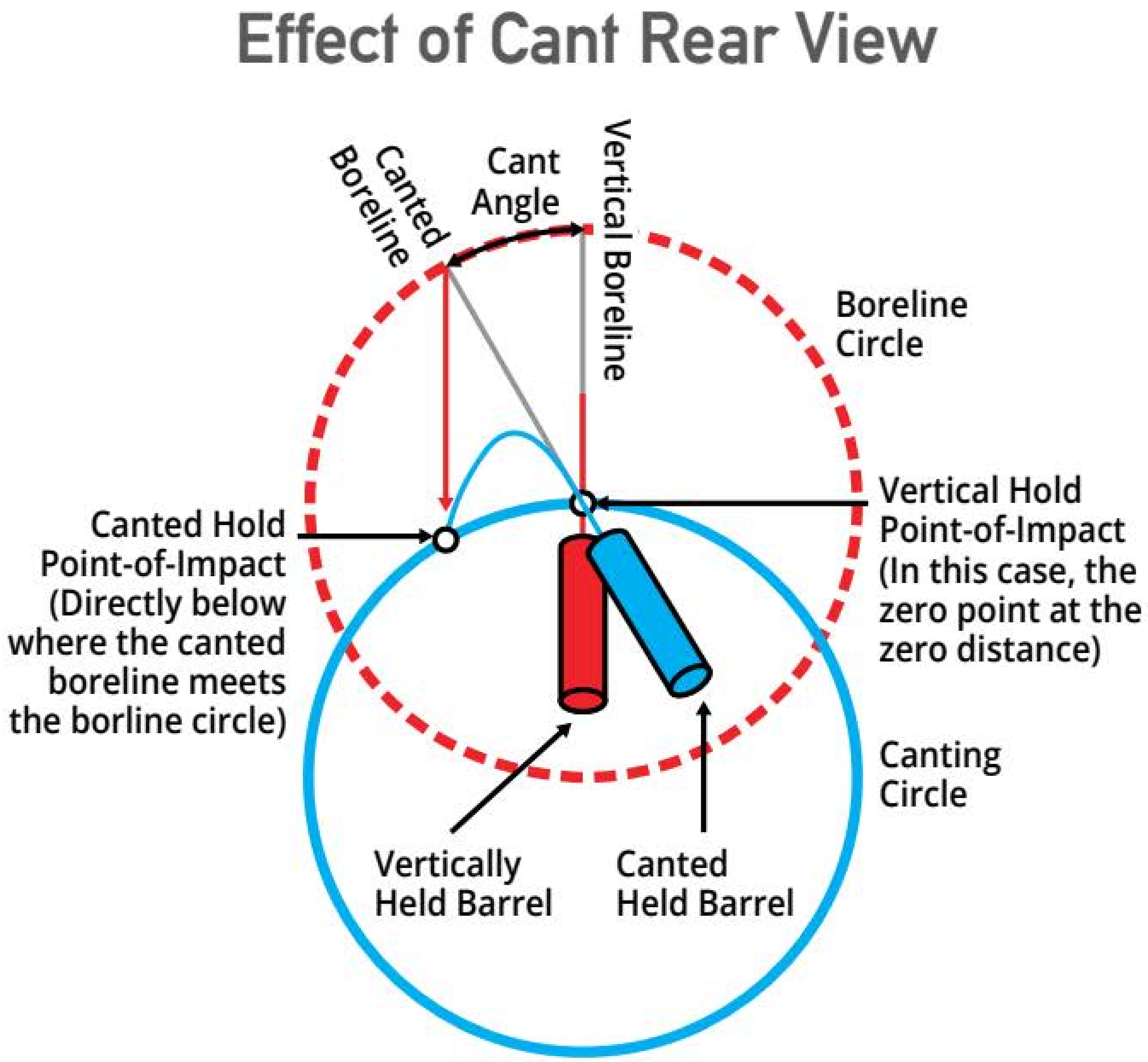

Effect of Cant Rear View
Canted Boreline
Cant Angle
Vertical Boreline
Boreline Circle
Canted Hold Point-of-Impact (Directly below where the canted boreline meets the borline circle)
Vertical Hold Point-of-Impact (In this case, the zero point at the zero distance)
Canting Circle
Vertically Held Barrel
Canted Held Barrel

Image 127: Small amounts of cant **have a noticeable windage error** but only a nominal elevation error. (See Image 126, Pg. 150.) This is because canting a rifle moves the point-of-impact around the canting circle, and moving away from the apex of the circle does not have much vertical change. The canting circle is based on the boreline circle. The boreline circle is the circle on the target that the boreline (a straight imaginary line coming out of the center of the bore) points at when the rifle is rotated about the sightline. The canted-hold point-of-impact on the canting circle is directly below where the canted boreline points on the boreline circle.

when properly aligned. They do this by zeroing the rifle with the point-of-aim to the left or right of the point-of-impact at a distance equal to the scope's horizontal offset from the bore.

14.c Reticle Cant

Many marksmen level their rifle by aligning the reticle (i.e., the lines seen projected onto the sight picture) (See Standard Reticles, Pg. 132.) to the horizon. However, this only works if the reticle is properly aligned so that its lines are exactly parallel or perpendicular to the force of gravity. Otherwise, rolling a rifle to level out the reticle may actually introduce cant to the rifle.

While **aligning a reticle to gravity is part of the scope mounting process**, it can be done whenever a marksman suspects their reticle is crooked. Realigning a reticle requires remounting the scope. To do so, a marksman can place a bubble level or electronic level on their rifle. Then, they place the reticle in the scope mount, but do not tighten it yet.

Then, the marksman creates a plumb line, which is a bright piece of string with a weight at the end (i.e., the plumb). (See Image 129, Pg. 153.) The plumb pulls the string into an exactly vertical position. The plumb line is positioned against a white wall or paper 10 m or yd away from the marksman. Then the marksman looks through their scope and rotates the scope in its mount until the vertical crosshair is aligned to the plumb line, at which point the reticle is level. When both the rifle and the reticle are simultaneously level, the marksman secures the scope to the rifle.

14.d Mechanical Adjustment Cant

Scopes have two separate components that are intended to be “plumb” (i.e., aligned to the direction of gravity). First, the reticle (i.e., the lines seen projected onto the sight picture) (See Standard Reticles, Pg. 132.) is built to have lines that are either exactly vertical or exactly horizontal with respect to gravity. Second, the adjustment turrets move the reticle within the scope housing exactly vertically or horizontally with respect to gravity. (See Adjusting Elevation and Windage Settings with Turrets, Pg. 36.) Therefore, since both components must be plumb, **a perfect scope would have the reticle aligned with its adjustment mechanisms**.

However, almost all scopes have some degree of misalignment between their reticle and their adjustment mechanisms. That is, if the reticle is aligned, then all adjustments pull the reticle slightly diagonally; and if the adjustments are aligned then the reticle would be crooked. While most manufacturers claim a limit on this misalignment, ranging from 0.5% to 5% depending on the company, scopes with perfect alignment are rare.

Also, misalignment error is random, so while some scopes of the same make and model are manufactured perfectly, others may have significant error. Therefore, to account for this error, marksmen must test the actual scope they intend to use.

Even after being properly calibrated, most scopes retain some degree of mechanical adjustment cant. This is because, unlike holding cant or reticle cant, **mechanical adjustment error is a feature of the equipment’s construction itself and cannot be fixed**. A marksman must choose between

Tools to Eliminate Cant

Image 128: This is a scope mount with a built-in **bubble level**. The level faces the marksman so they can observe it and eliminate holding cant just before looking into the sight picture. It can also be used during scope mounting to eliminate reticle cant.

Image 129: A **plumb line** is a bright string with a weight (i.e., the plumb) attached to the end that pulls the string straight down. "Plumb" comes from the Latin word for "lead" and while these plumbs are specialized, any heavy weight works equally well.

leveling their reticle and leveling their adjustment mechanisms. And a plumb reticle is preferable to plumb adjustment mechanisms because reticles are used more often and are easier to plumb than adjustment mechanisms.

The best way to measure the diagonal mechanical adjustment error in a rifle system is to perform a **tall target test**. To conduct a tall target test, a marksman must first ensure that their reticle is plumb and that their rifle is zeroed. In fact, the tall target test is a good addition to the end of the zeroing process for any scope new to the marksman. (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.)

First, the marksman sets up a 1.5-m-or-yd-tall target at a distance of 100 m or yd (or a target of the same relative height at the rifle's zero distance). On the target, they use a plumb line to draw a perfectly vertical line from the top to the bottom of the target. Because both the reticle and the target have a plumbed line, the marksman can ensure no scope cant by aligning the reticle to the target's line.

Thereafter, the bottom of the line becomes the point-of-aim for all subsequent shots. The marksman then fires a five-shot group at the bottom of the line. (See Grouping, Pg. 74.) After this initial group, the elevation turret is adjusted upward by 3 mils (or 10 MOA), and another five-shot group is fired while aiming at the bottom of the line. This process is repeated two more times, resulting in a total of four groups. The center-averages of these groups are then connected to form a line. If this line is angled in relation to

Mechanical Adjustment Cant

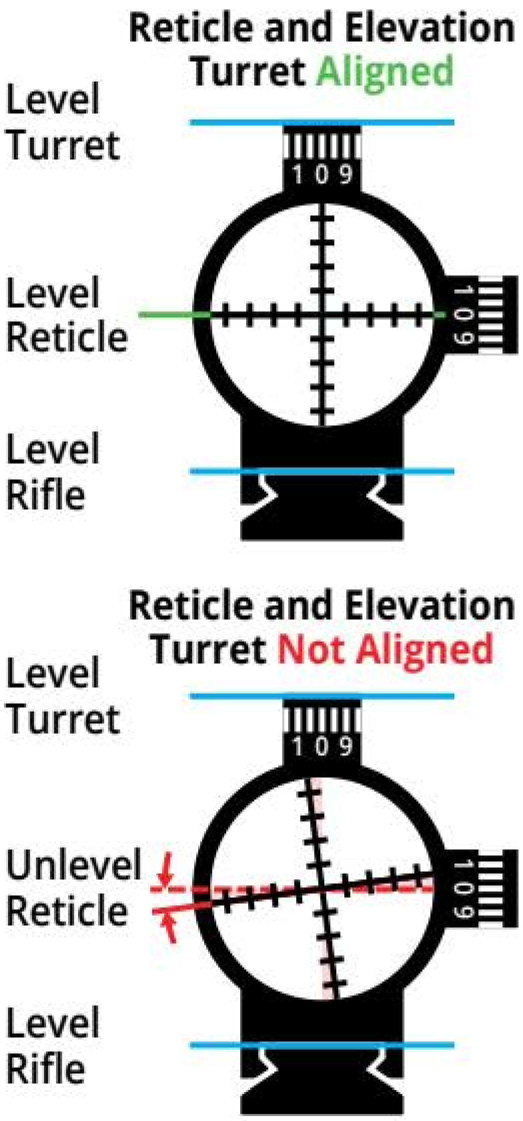

Reticle and Elevation Turret Aligned
Level Turret
1 0 9
Level Reticle
1 0 9
Level Rifle
Reticle and Elevation Turret Not Aligned
Level Turret
1 0 9
Unlevel Reticle
1 0 9
Level Rifle

Image 130: When turrets are level, reticles are also supposed to be level (top). However, **due to manufacturing errors**, many scopes are produced with reticles and turrets that are misaligned (bottom). If a marksman vertically aligns the turrets of a misaligned scope, then holding for elevation introduces windage error. If a marksman vertically aligns the reticle then dialing for elevation introduces windage error.

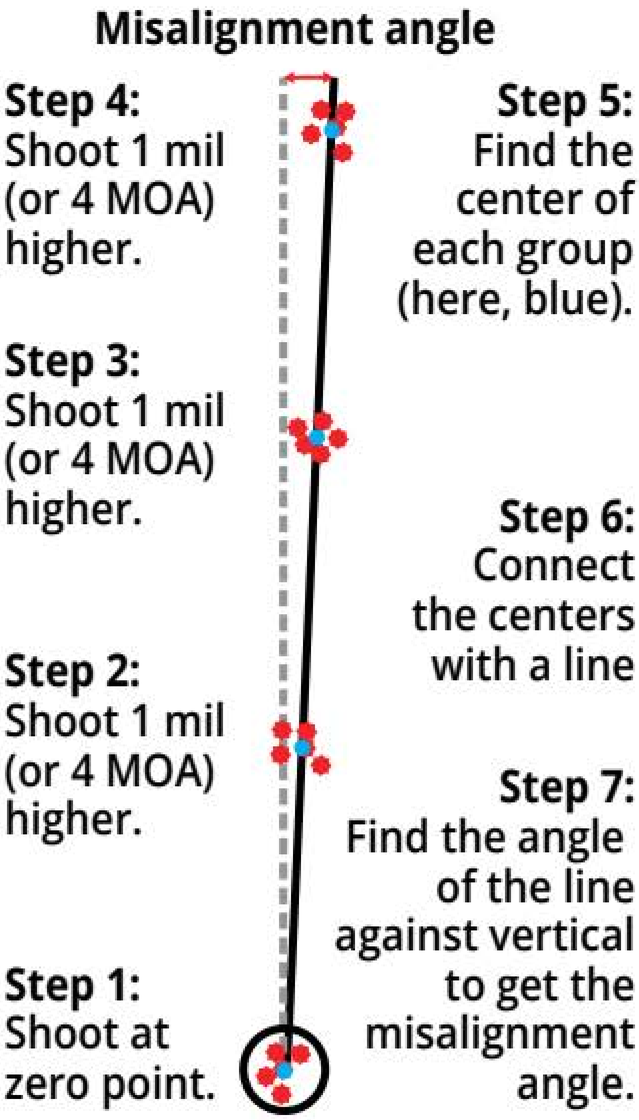
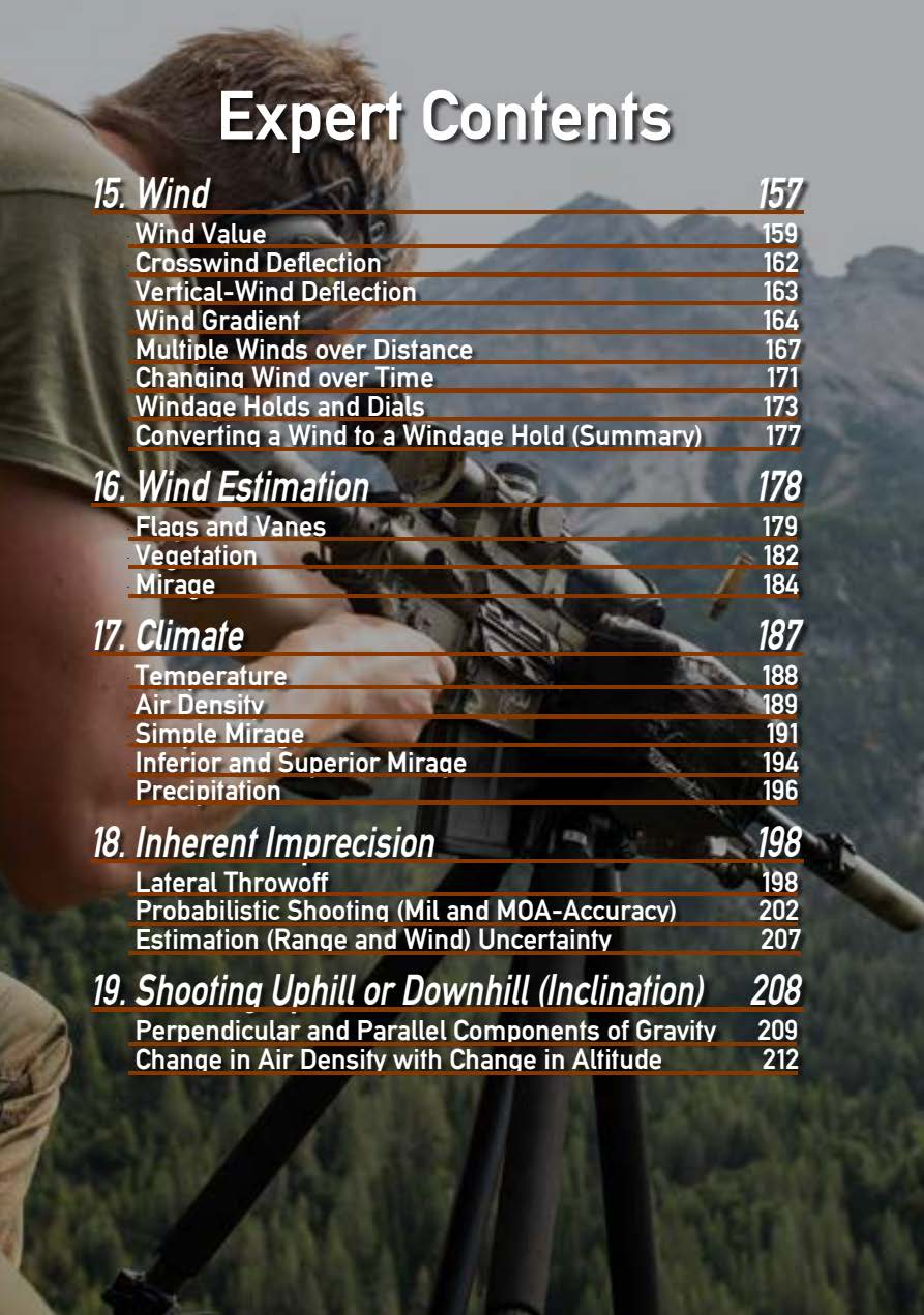

Misalignment angle
Step 4: Shoot 1 mil (or 4 MOA) higher.
Step 5: Find the center of each group (here, blue).
Step 3: Shoot 1 mil (or 4 MOA) higher.
Step 6: Connect the centers with a line
Step 2: Shoot 1 mil (or 4 MOA) higher.
Step 7: Find the angle of the line against vertical to get the misalignment angle.
Step 1: Shoot at zero point.

Image 131: A marksman can conduct a **tall-target test** to determine the misalignment angle between a reticle and an elevation turret. The marksman shoots groups at increasing elevation (either dialing or holding) and then connects the group's centers. If the line that connects the group's centers is plumb (here, the dotted line), then the reticle and turrets are aligned. If there is an angle between the line and plumb, then they are misaligned.

the vertical line, the angle represents the difference between the reticle and turret adjustments.

Entirely separately from reticle cant, the results of the tall target test can also tell the marksman what one click on their scope mechanism actually represents. For example, if a scope advertises that each click is 1/10 of a mil, then rotating the elevation turret 30 times would elevate the reticle by 3 mils. At 100 meters, that is a vertical difference of 30 cm. However, if the actual average distance between the center-averages of the four groups is 27 cm, then a marksman knows that each click only actually rotates a turret by 10% less than advertised by the manufacturer, or about 1/11 of a mil.

Significant discrepancies between what a click is advertised to rotate versus what it actually rotates can cause marksmen to over or under adjust. And even if a marksman becomes accustomed to their own equipment, inaccurate click adjustments can cause issues when they use other equipment or when equipment is shared. In fact, whenever marksmen complain about variations in ammunition performance across different rifles, the culprit may actually be the performance of the scopes (i.e., the tools used to measure the performance of the ammunition).



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Experts
(300 to 600 Meters or Yards)

> *An expert is someone who has made all the mistakes which can be made in a very narrow field.*
>
> *—Niels Bohr, Danish, Nobel-Prize-winning physicist*

Defining skill level with distance is arbitrary. However, the 300-m-or-yd mark often serves as a practical cutoff for human vision, and the beginning of considering environmental conditions. That is, even seasoned hunters and military marksmen must rely on advanced optics and calculations to maintain accuracy beyond 300 m or yd. These calculations take into account variables such as wind, probability, and inclination. And the required skills for these calculations include reading and understanding: tables and charts, environmental conditions, and basic statistics and trigonometry.

15. Wind

Wind is the fluid movement of air. It affects the air resistance that bullets experience as they travel because air resistance is directly correlated to the differential speed between a bullet and the air surrounding it. If air moves against the bullet, resistance increases; and if air moves with the bullet, resistance decreases.

At close distances, wind has a minimal impact on bullets and is often discounted as a factor that can affect accuracy. This is because wind acts on bullets over time, and at close distances a bullet simply does not spend enough time in the air for wind to significantly change its trajectory.

However, as bullets travel longer distances, the influence of wind becomes more significant as wind has more time to act on the bullet. In fact, **the impact of wind grows exponentially with distance**, as not only does the bullet have farther to travel, but it also slows down during flight. Therefore, accounting for wind becomes critical for accurate shooting at longer distances. Specifically, concepts such as wind value, crosswind deflection, vertical wind deflection, wind gradient, and changing winds are crucial in determining a projectile's trajectory. To combat these wind effects and ensure consistent accuracy, marksmen must employ windage holds and windage charts.

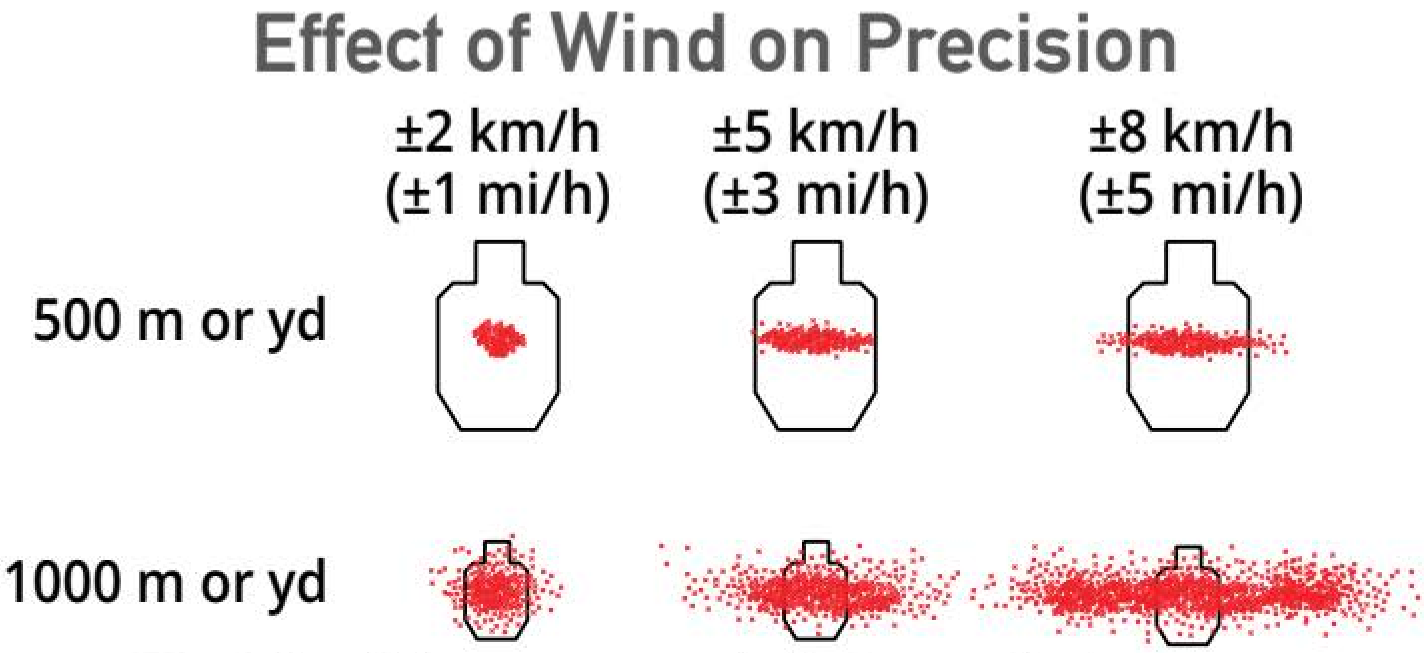


Image 132: Each red dot represents a bullet impact. The impacts are more dispersed at 1000 m or yd than at 500 m or yd because **wind has more time to deflect the bullets**. In contrast, the target size appears to shrink as it gets farther. These two contrasting effects cause the skill of estimating wind to quickly go from unimportant to very important as targets get farther from the marksman.

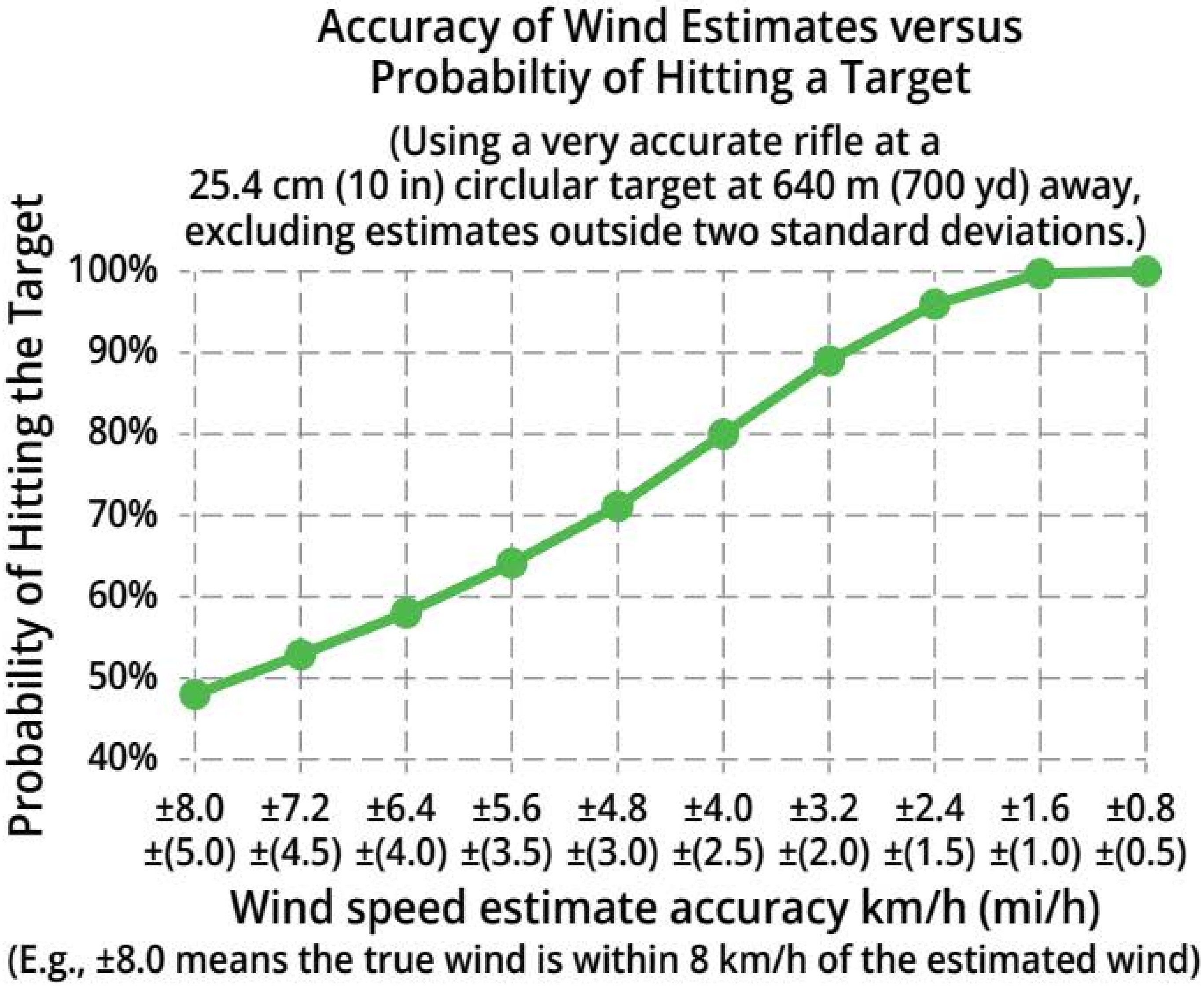


Image 133: This graph shows that **becoming more accurate at estimating wind speed can quickly make a marksman more accurate**. This curve is a "sigmoid," which means that it starts slow, ramps up quickly, and then plateaus. In other words, marksmen who are very bad and very good at wind calls may not see too much immediate benefit from more accurate estimates; but marksmen who are in the middle skill area see fast improvement. (Of course, an advanced marksman at one distance can be just an intermediate marksman at a farther distance.)

Finding Wind Direction

Image 134: Marksmen with electronic wind meters (a.k.a., "anemometers") rotate their meter 360 degrees. The **direction with the highest reading** is the direction of the wind.

Image 135: The classic way to find the direction of the wind is to hold, drop, or watch something light, such as fabric or leaves, in the air and watch which way the wind blows it.

Image 136: This man measures the wind's speed with a wind meter, and the wind's direction with a compass.

Image 137: If a marksman is staying in one place for a while, they can set up a portable tripod vane.

15.a Wind Value

Wind can come from any direction in three-dimensional space: left-right (crosswind), forward-back (headwinds and tailwinds), and up-down (vertical wind). However, headwinds and tailwinds have little effect on bullets, and vertical winds are uncommon. Therefore, the most important "wind" for a marksman to understand is not the actual wind, but the component of the wind that blows perpendicular to the bullet's path. This left-right component is known as the "equivalent crosswind," and the equivalent crosswind's percent of the overall wind is the "wind value" (measured in percent).

The calculation of the wind value involves two steps. First, the marksman determines which direction the wind is blowing from. (See Finding Wind Direction, Pg. 159.) This is not a precise measure because wind constantly

Wind Value Chart

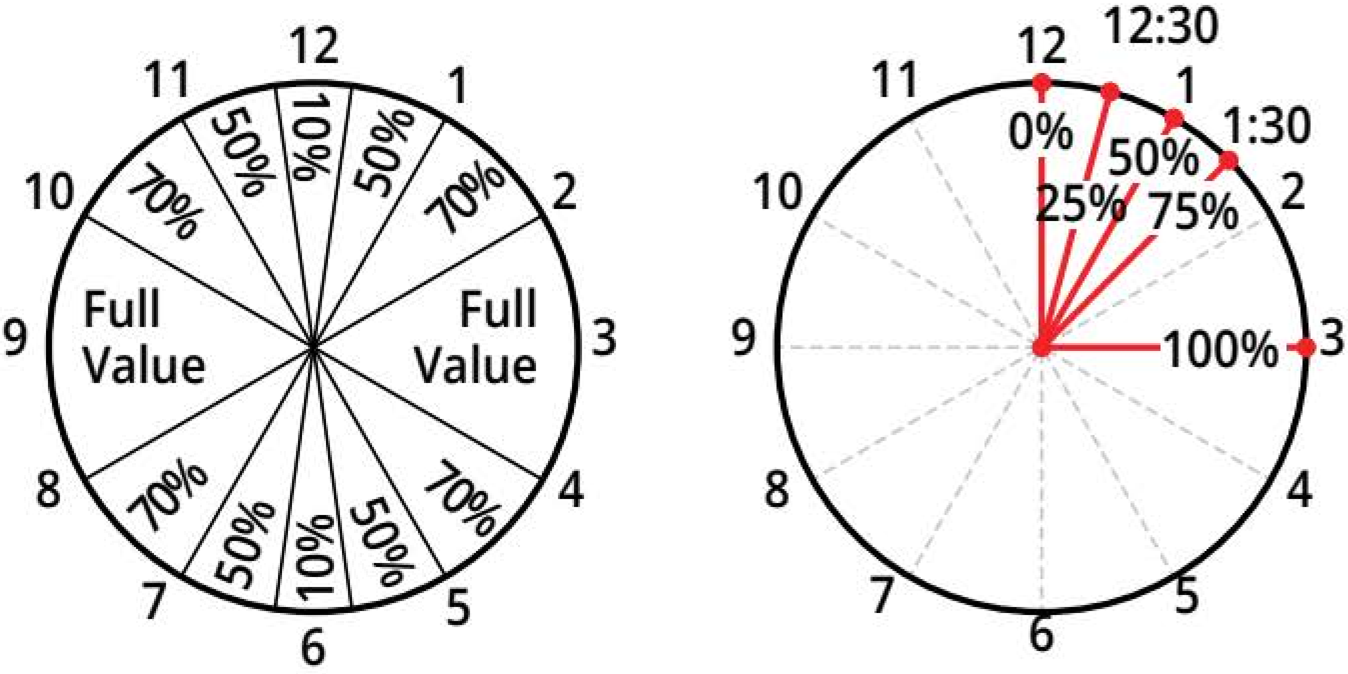
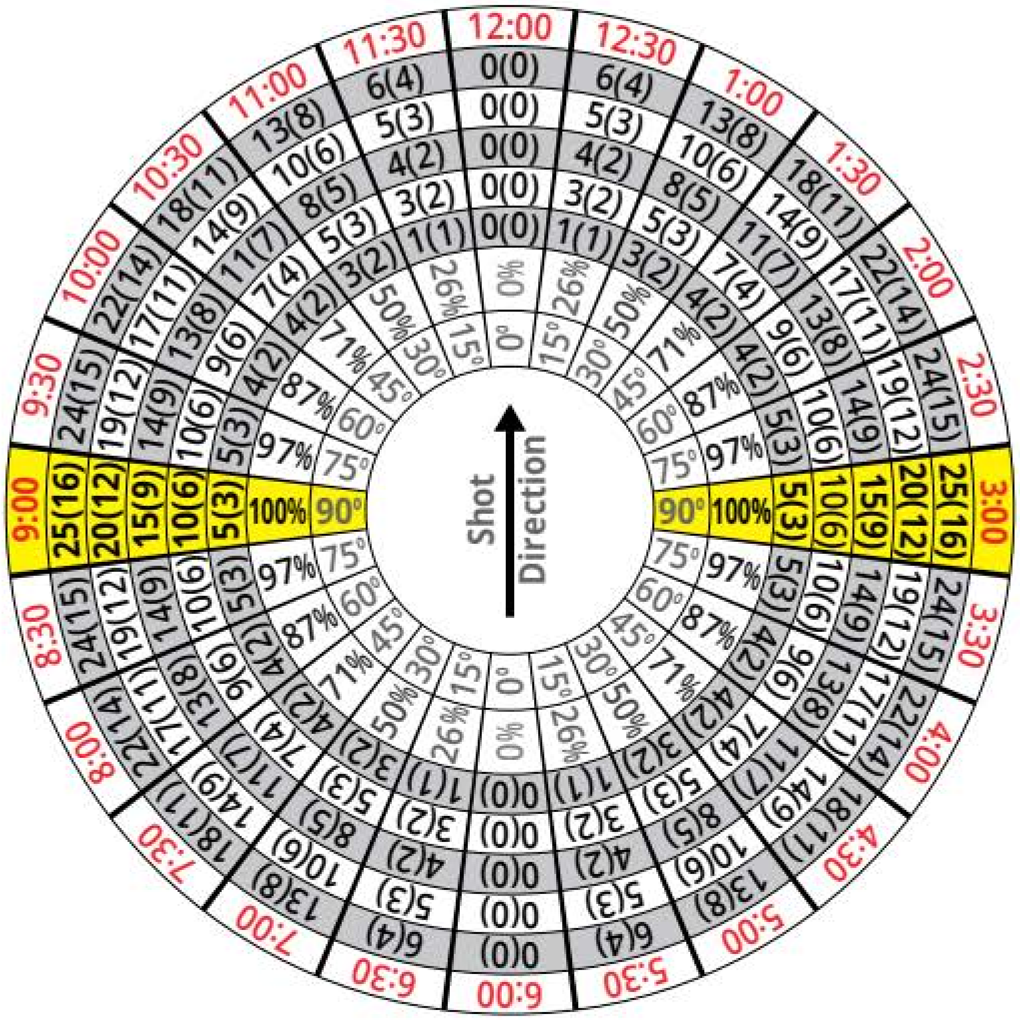


Image 138: Wind value is based on where the wind comes from. The most common method of finding a wind value is to use the clock system, where the marksman is pointing at 12 o'clock. A parallel wind (12 and 6 o'clock) has no value, while a crosswind (9 and 3 o'clock) has a full value. On the left is the simplest system a marksman can use, with only 4 values: 100%, 70%, 50%, and 10%. This becomes less precise as the wind comes closer to 12 or 6 o'clock, and the percentages change quickly. On the right are the wind values for specific clock locations.


Shot Direction

12:00	0°	0%	0(0)	0(0)	0(0)	0(0)	0(0)
12:30	15°	26%	1(1)	3(2)	4(2)	5(3)	6(4)
1:00	30°	50%	3(2)	5(3)	8(5)	10(6)	13(8)
1:30	45°	71%	4(2)	7(4)	11(7)	14(9)	18(11)
2:00	60°	87%	4(2)	9(6)	13(8)	17(11)	22(14)
2:30	75°	97%	5(3)	10(6)	14(9)	19(12)	24(15)
3:00	90°	100%	5(3)	10(6)	15(9)	20(12)	25(16)
3:30	75°	97%	5(3)	10(6)	14(9)	19(12)	24(15)
4:00	60°	87%	4(2)	9(6)	13(8)	17(11)	22(14)
4:30	45°	71%	4(2)	7(4)	11(7)	14(9)	18(11)
5:00	30°	50%	3(2)	5(3)	8(5)	10(6)	13(8)
5:30	15°	26%	1(1)	3(2)	4(2)	5(3)	6(4)
6:00	0°	0%	0(0)	0(0)	0(0)	0(0)	0(0)
6:30	15°	26%	1(1)	3(2)	4(2)	5(3)	6(4)
7:00	30°	50%	3(2)	5(3)	8(5)	10(6)	13(8)
7:30	45°	71%	4(2)	7(4)	11(7)	14(9)	18(11)
8:00	60°	87%	4(2)	9(6)	13(8)	17(11)	22(14)
8:30	75°	97%	5(3)	10(6)	14(9)	19(12)	24(15)
9:00	90°	100%	5(3)	10(6)	15(9)	20(12)	25(16)
9:30	75°	97%	5(3)	10(6)	14(9)	19(12)	24(15)
10:00	60°	87%	4(2)	9(6)	13(8)	17(11)	22(14)
10:30	45°	71%	4(2)	7(4)	11(7)	14(9)	18(11)
11:00	30°	50%	3(2)	5(3)	8(5)	10(6)	13(8)
11:30	15°	26%	1(1)	3(2)	4(2)	5(3)	6(4)

Image 139: This wind value table uses the same values as the table to the right, but in a clock format. To use this chart, first, find the actual wind speed in either yellow slice. Then rotate around the circle to the direction the actual wind is coming from. The resulting cell contains the equivalent crosswind in km/h (mi/h).

Actual Wind to Equivalent Crosswind

Wind Direction		Wind Speed in Kilometers (Miles) per Hour									
Degrees	O'clock	5 (3)	10 (6)	15 (9)	20 (12)	25 (16)	30 (19)	35 (22)	40 (25)	45 (28)	50 (31)
0°	12:00, 6:00	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
10°		1 (1)	2 (1)	3 (2)	3 (2)	4 (3)	5 (3)	6 (4)	7 (4)	8 (5)	9 (5)
15°	11:30, 12:30, 5:30, 6:30	1 (1)	3 (2)	4 (2)	5 (3)	6 (4)	8 (5)	9 (6)	10 (6)	12 (7)	13 (8)
20°		2 (1)	3 (2)	5 (3)	7 (4)	9 (5)	10 (6)	12 (7)	14 (9)	15 (10)	17 (11)
30°	11:00, 1:00, 5:00, 7:00	3 (2)	5 (3)	8 (5)	10 (6)	13 (8)	15 (9)	18 (11)	20 (12)	23 (14)	25 (16)
40°		3 (2)	6 (4)	10 (6)	13 (8)	16 (10)	19 (12)	22 (14)	26 (16)	29 (18)	32 (20)
45°	10:30, 1:30, 4:30, 7:30	4 (2)	7 (4)	11 (7)	14 (9)	18 (11)	21 (13)	25 (15)	28 (18)	32 (20)	35 (22)
50°		4 (2)	8 (5)	11 (7)	15 (10)	19 (12)	23 (14)	27 (17)	31 (19)	34 (21)	38 (24)
60°	10:00, 2:00, 4:00, 8:00	4 (3)	9 (5)	13 (8)	17 (11)	22 (13)	26 (16)	30 (19)	35 (22)	39 (24)	43 (27)
70°		5 (3)	9 (6)	14 (9)	19 (12)	23 (15)	28 (18)	33 (20)	38 (23)	42 (26)	47 (29)
75°	2:30, 3:30, 8:30, 9:30	5 (3)	10 (6)	14 (9)	19 (12)	24 (15)	29 (18)	34 (21)	39 (24)	43 (27)	48 (30)
80°		5 (3)	10 (6)	15 (9)	20 (12)	25 (15)	30 (18)	34 (21)	39 (24)	44 (28)	49 (31)
90°	3:00, 9:00	5 (3)	10 (6)	15 (9)	20 (12)	25 (16)	30 (19)	35 (22)	40 (25)	45 (28)	50 (31)

Image 140: This table takes the actual horizontal wind speed (X-axis) and the wind's direction (Y-axis), and outputs the **equivalent crosswind (cell contents)**. The value is found by multiplying the wind speed by the sine of the degree (See Image 178, Pg. 210.), when the direction the marksman faces is 0 degrees.

changes direction. At a distance, marksmen can observe vegetation or flags to see in which direction they are blowing. (See Wind Estimation, Pg. 178.)

Because wind measurements are imprecise, they typically are put into an "o'clock system." (See Image 138, Pg. 160.) Imagine the marksman is standing in the middle of a clock, with the target straight ahead at 12 o'clock. If the wind is blowing directly from the front, it's coming from 12 o'clock. If it's coming from directly behind, it's at 6 o'clock. Winds from the right side are at 3 o'clock, and winds from the left are at 9 o'clock.

The second step is to input the wind direction into a lookup table or chart to find the wind-value percentage. The wind value is then multiplied by the full wind speed to obtain the equivalent crosswind speed. (See Image 139, Pg. 160.) For example, if the marksman estimates a 15 km/h (9.3 mi/h) wind blowing at a 90° angle to the bullet, the wind value is 100%, resulting in an equivalent crosswind speed of 15 km/h (9.3 mi/h). However, if the wind is blowing at a 45° angle to the trajectory, the wind value is only 71%, leading to an equivalent crosswind speed of approximately 11 km/h (15 km/h × 71% ≈ 11 km/h) or 6.8 mi/h (9.3 mi/h × 75% ≈ 6.8 mi/h).

15.b Crosswind Deflection

To deflect is to cause something to change its direction. That is, "deflection" is a technical way of saying "push." So "crosswind deflection" is how a left-right wind pushes a bullet sideways off its original path-of-travel. A crosswind is named based on the direction it comes from. For example, a "left wind" blows from left to right. To account for a crosswind, a marksman uses a windage hold or dial. (See Windage Holds and Dials, Pg. 173.)

Crosswind deflection is more important than tailwind and headwind deflection because bullets are designed to be aerodynamic (i.e., ignore air resistance) in the direction they travel. But their design does not prioritize preventing a crosswind from pushing them sideways. Crosswinds are more important than vertical-winds (updrafts and downdrafts) simply because crosswinds are far more common, although their effect is the same.

Wind-deflected bullets behave in a way that might seem counterintuitive: they actually point into the wind, not away from it. This happens because the front of the bullet, having a smaller surface area, experiences less wind force than the thicker rear section. As a result, the wind pushes the rear more than the front, causing the bullet to rotate and align itself toward the direction of the wind. (See Image 141, Pg. 163.) Also, the same gyroscopic effect from spinning that causes bullets to point forward causes them to point into all incoming air resistance, including wind. Pointing into incoming air resistance is referred to as "weathervaning," as it is similar to how weathervanes align with the wind.

The amount of rotation a bullet experiences is directly proportional to the ratio of the crosswind to the bullet's speed. For example, a crosswind of 20 km/h (12 mi/h) is approximately 1% of the wind that a bullet traveling at 2,000 km/h (1,240 mi/h) encounters. This means that the bullet may rotate about 1% or roughly 1° into the wind. The rotation happens rapidly as the bullet travels through the air, and the new orientation persists as long as the wind persists. Therefore if the wind stops, a bullet's tip realigns itself with the direction-of-travel (i.e., the direction of incoming air resistance).

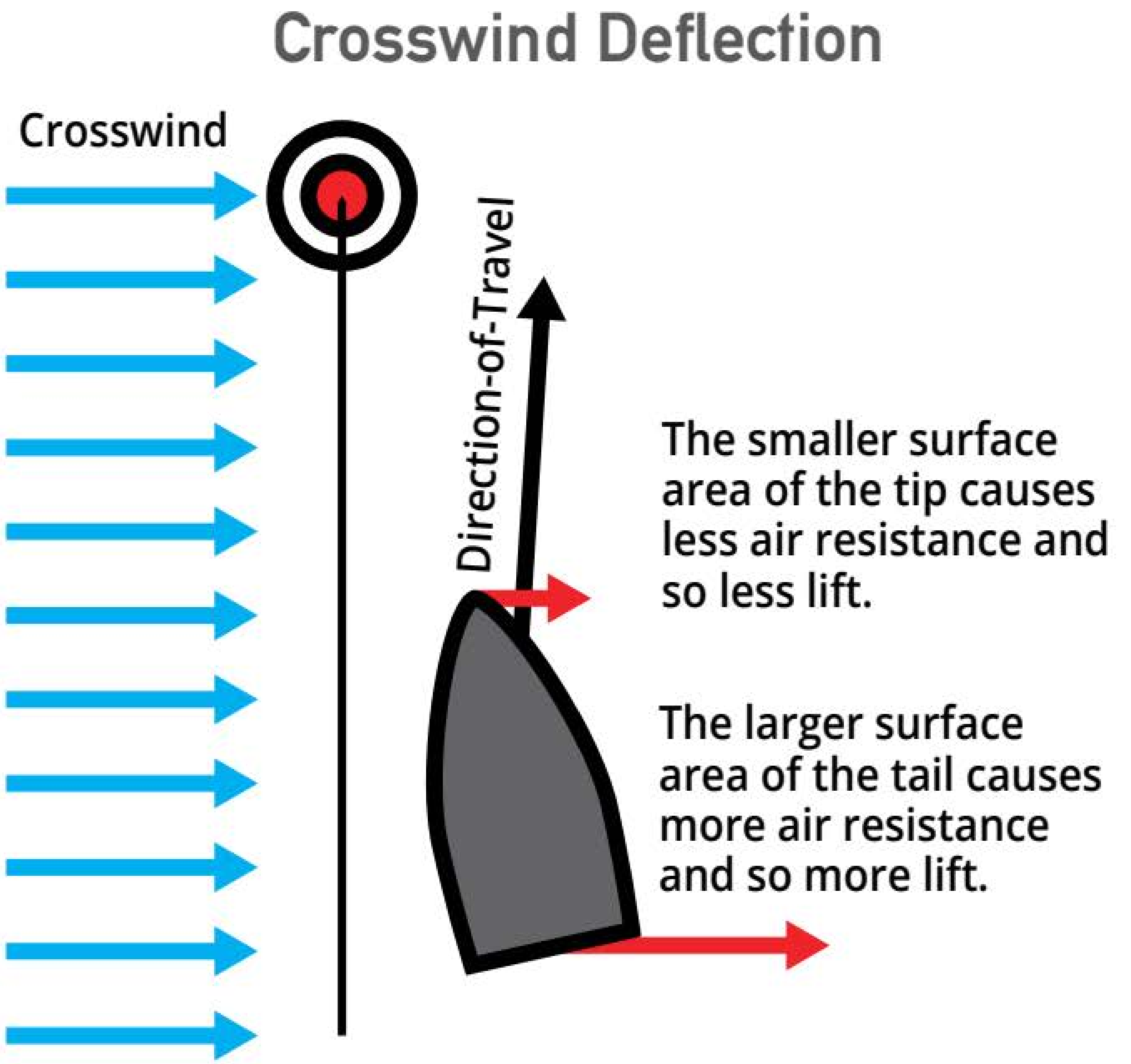

Crosswind Deflection
Crosswind
Direction-of-Travel
The smaller surface area of the tip causes less air resistance and so less lift.
The larger surface area of the tail causes more air resistance and so more lift.

Image 141: Crosswinds push bullets sideways, deflecting them off of their original course onto a new trajectory. In this diagram, the left-to-right crosswind has deflected the bullet sideways, so its direction-of-travel is now shifted to the right. However, at the same time, the bullet rotates to face the crosswind because its tip is less affected by the crosswind compared to its tail. Although this diagram is intended to be from a top-down perspective, this diagram would also apply equally to vertical winds if it were a side view.

15.c Vertical-Wind Deflection

Vertical-wind deflection caused by updrafts and downdrafts operates identically to crosswind deflection but at a 90° angle. Most long-range shooting locations have natural features that cause updrafts and downdrafts which the wind must pass over. However, these obstacles often generate an upward wind on one side and a downward wind on the other side, effectively neutralizing each other. Therefore, to observe a vertical-wind effect, a bullet must only travel over a portion of an obstacle or have a significant distance between the updraft and downdraft.

Therefore, the most common situation where significant vertical wind occurs is when targets are positioned on large cliffs. When wind hits a cliff, it has nowhere to go but up. When a wind falls over a cliff, it must go down. (See Image 149, Pg. 169.) This is most often a consideration for inclined shooting. (See Shooting Uphill or Downhill (Inclination), Pg. 208.) Overall however, vertical wind is always connected to nearby terrain features. (See Image 142, Pg. 165.) So, the most effective way to detect vertical wind is to remember that air behaves like a fluid, and therefore consider how a fluid may interact with the surrounding terrain.

Vertical wind deflects bullets up and down, and so marksmen must compensate for it with an elevation hold or dial (See Elevation Hold and Dial, Pg. 136.) and not a windage hold or dial (See Windage Holds and Dials, Pg. 173.) which is specifically used for crosswind deflection.

15.d Wind Gradient

At higher altitudes, the wind blows faster due to the wind's reduced friction with the ground. This increase in wind speed at higher elevations causes bullets to **experience a stronger wind** than would be implied by the wind speed at ground level alone.

Even at a height of 5 m (5.5 yd) above the ground, the wind can be significantly faster than at ground level, and this speed increases every 5 m (5.5 yd) above that. The severity of the gradient depends on how frictional the ground is. For example, trees greatly impede ground wind from blowing, and so they cause a more severe wind gradient than grass does. In fact, a forest may experience a wind speed increase from 0 to 50 km/h (31 mi/h) from below to above its canopy. In contrast, a desert or frozen lake may have almost no wind gradient (i.e., wind speed at ground level would be the same as the wind speed at a higher altitude). Consequently, when determining wind speed at a particular location on a range, the marksman must take into account the bullet's elevation along its trajectory and account for the wind speeds at those elevations in addition to the ground-level wind speed.

A bullet's precise trajectory is not necessary to account for a wind gradient, and instead **the wind gradient can be estimated** by finding the apex of the bullet's travel. This happens because wind direction and speed are constantly changing, so any precise measurements quickly become outdated and turn into rough estimates anyway.

To estimate the apex, a marksman can use the following process. First, they picture their bullet traveling in a straight line upward for the first half of the distance to the target, and then in a straight line downward for the second half. For example, if the target is positioned 1,000 m (1,090 yd) away from

Image 142: A Belgian special operations sniper takes aim at targets across a valley. Hochfilzen Training Area, Austria, 11 Sep 2018. When shooting over a valley or depression, marksmen must consider **wind gradients**. Marksmen near cliffs, especially those who shoot parallel to a cliff, must also be aware of the possibility of **updrafts** deflecting their bullets up and **downdrafts** deflecting them down.

the marksman, halfway to the target would be at 500 m (547 yd). Then, the marksman determines the apex of the bullet's travel. For example, assume a marksman compensates for bullet-drop by aiming the center of their reticle 10 mils high (i.e., an elevation hold of 10 mils), which translates to a height of 5 m (5.5 yd) at 500 m (547 yd). (1 mil is defined as 1 m of height at a distance of 1000 m. So, at 500 meters away, 10 mils would have a height of 5 m.) This calculation determines the height of the apex for a triangular shape, but since bullets follow a curved trajectory, the apex can be estimated as half of the height of the theoretical triangle. Therefore, in this example, the bullet's maximum height may be approximately 2.5 m.

Accounting for wind gradients is typically necessary only for very long shots. However, as the distance to the target increases, the height of the bullet's apex rises rapidly. This is because the upward angle at which marksmen must aim **grows exponentially** with the distance to the target. In the example provided, if the distance is doubled, the bullet's apex rises to three times its original height.

That being said, wind gradient remains relevant in a different capacity when shooting at distances of 500 m (547 yd) and beyond. Marksmen must take into consideration **faster winds that occur over valleys or depressions** and remember that the maximum speed in these cases does not apply to the

Wind Gradient

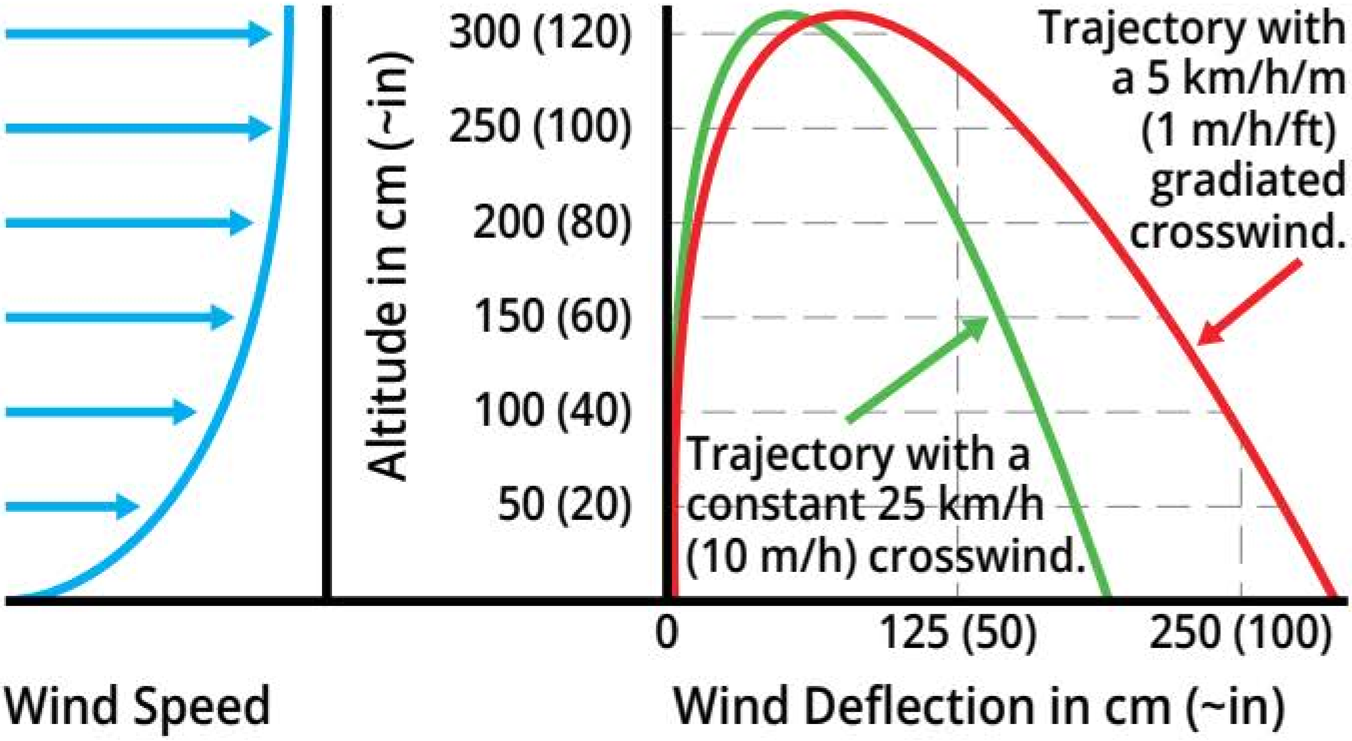


Image 143: The graph on the left shows what a wind gradient is: as altitude increases (Y-axis), wind speed (X-axis) also increases. The diagram on the right shows how powerful a wind gradient can be for high-altitude shots. The shorter curve shows how much a bullet fired in a crosswind of constant power would be deflected. The longer curve shows what happens when the crosswind speed is low (close to the ground) and high (far from the ground) (i.e., a wind gradient). When a bullet is fired in a wind gradient, the wind speed quickly surpasses the speed of the constant crosswind, thereby deflecting a bullet much farther overall.

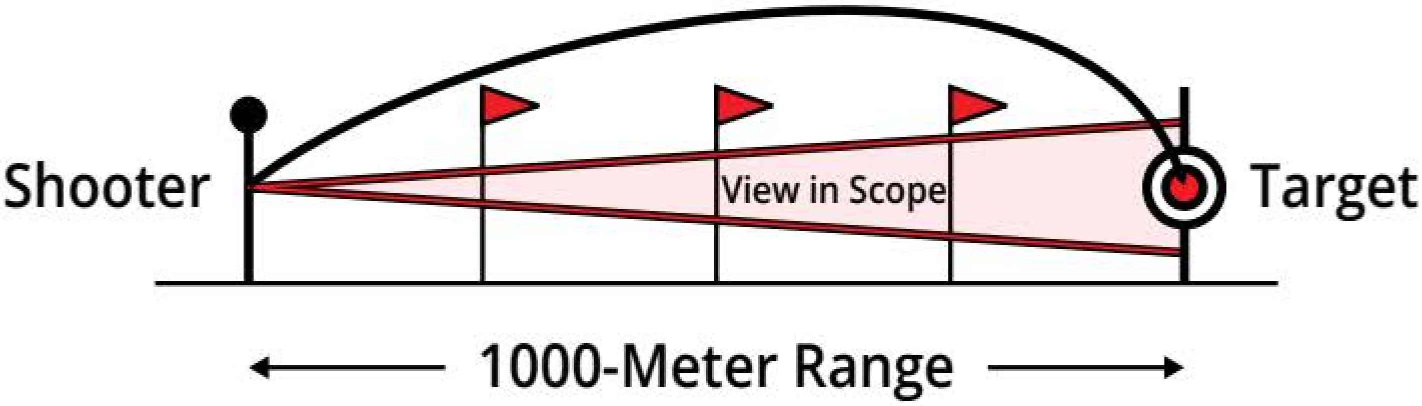


Image 144: **Wind gradients also affect the ability of marksmen to read the wind** because the indicators that marksmen use to determine wind speed, such as mirage or flags, can be below the trajectory of the bullet.

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entire trajectory of the bullet and must be considered as a separate wind. (See Multiple Winds over Distance, Pg. 167.)

Even if a marksman can determine a bullet's apex, precisely determining a wind gradient is difficult because the typical ways to estimate wind speed do not work in the sky. (See Image 144, Pg. 166.) For example, vegetation slows the wind, so cues from vegetation do not accurately reflect the wind speed above it. Additionally, simple mirage disappears at 10 m (11 yd) above the ground. (See Mirage, Pg. 184.) To compensate for this, most marksmen simply add a few km/h or mi/h to the speed of the prevailing wind for every 5 m (5.5 yd) above the ground that the bullet travels.

That being said, one indicator that can inform a marksman about the wind speed in the sky is **the presence of gusts** on the ground. A "gust" is a sudden, strong rush of wind that overrides the prevailing wind for a short period of time. When a gust occurs, the marksman can infer that the gust is moving at the same speed as a higher wind.

DOPE books can also be helpful; marksmen may be able to determine the wind gradient of an area by looking at their previous engagements and figuring out how each variable affected their shooting. If every variable except wind is accounted for, the marksman can reasonably infer information about the wind in an area, and thereby deduce what wind gradient must be present.

15.e Multiple Winds over Distance

Because wind is fluid, it is never consistently uniform across a range. Typically, the wind is consistent enough that a single wind measurement at any point is sufficient for generalization. However, this is not always the case, and marksmen may encounter significant variations at different areas along a bullet's path, especially if it travels far. (See Image 145, Pg. 168.)

In fact, **when shooting over different kinds of terrain, marksmen can assume that there are multiple winds, one for each terrain type**. To calculate the overall wind effect, a marksman can divide the bullet's trajectory into equal sections, assign each section a wind speed and a wind value, and then average the equivalent crosswinds for each section. (See Wind Value, Pg. 159.) Marksmen typically only divide the bullet's trajectory into two sections (near and far) or three sections (near, middle, and far) to minimize the number of measures they take.

After calculating the equivalent crosswind (EC) for each section (See Wind Value, Pg. 159.), these sections are combined using a **weighted average**. A weighted average is a method of computing an average where some data points contribute more than others. In this case, weights are necessary because wind affects a bullet's trajectory more when the wind is closer to the marksman than when it's closer to the target. This is because winds change the bullet's trajectory, and the earlier this happens, the more time the bullet has to deviate from its original trajectory. Therefore, winds closer to the marksman are given more weight in the averaging process. (See Image 146, Pg. 168.)

Multiple Winds over Distance

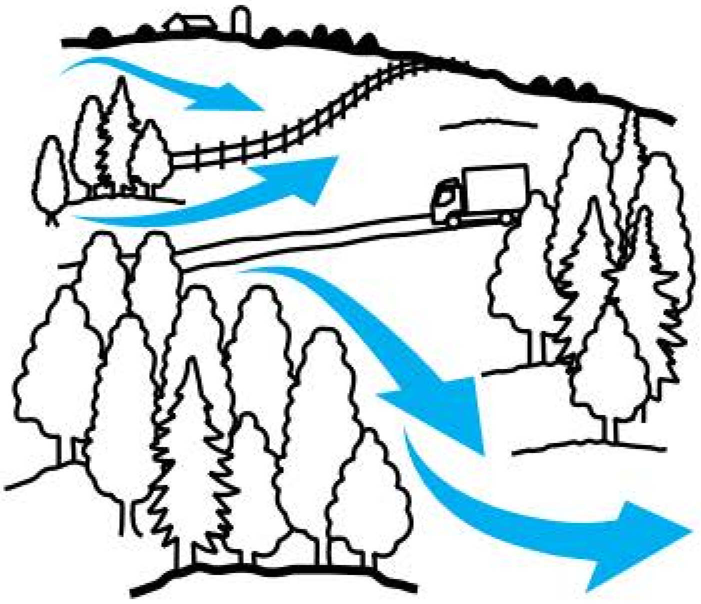

Image 145: **Wind follows terrain**, and so marksmen must take multiple wind readings when shooting at longer distances over changing terrain.

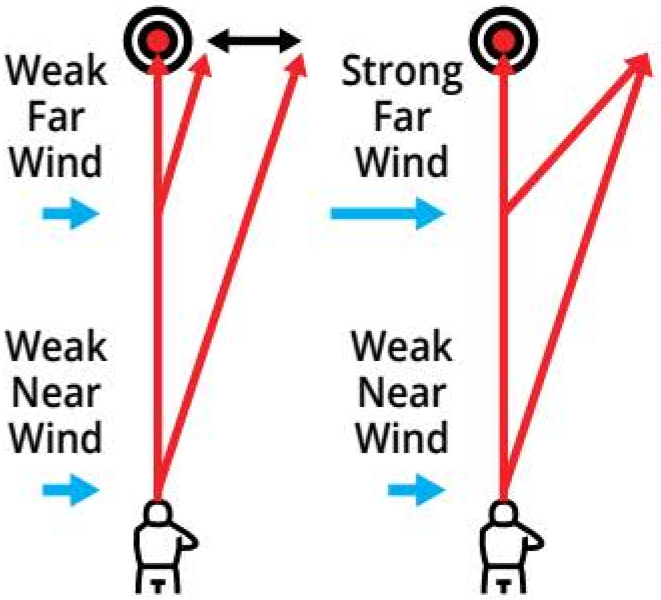

Image 146: **Winds nearer to the marksman have a greater effect** because they deflect bullets sooner (left). For the same effect as a near wind, a far wind must deflect the bullet at a steeper angle (right).

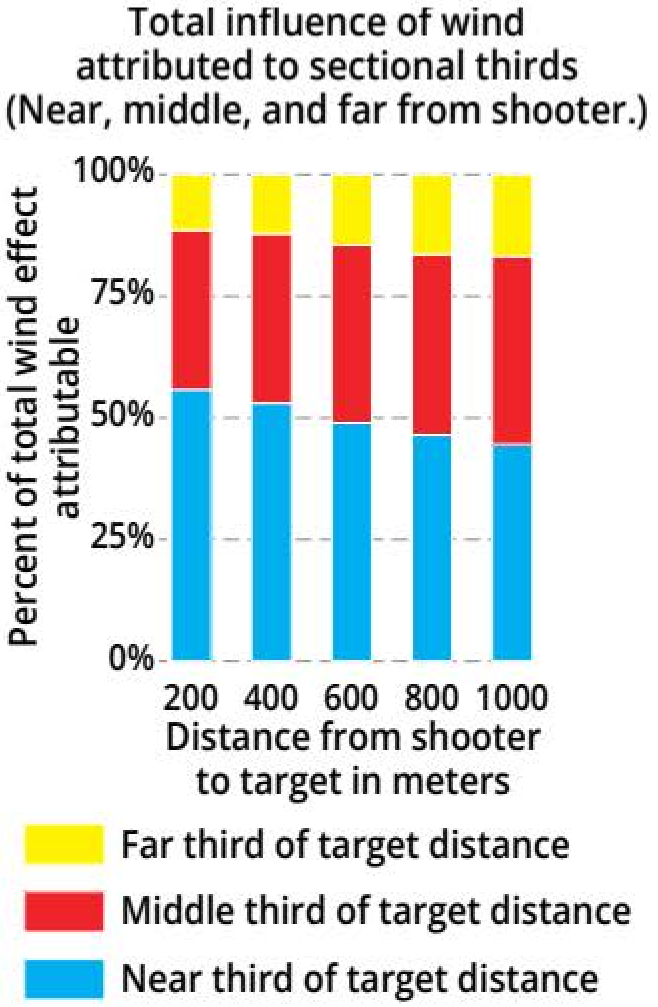

Image 147: The wind near a marksman has more effect on a bullet's trajectory than wind far from a marksman. This diagram also shows that the far third has more influence as total distance to the target increases.

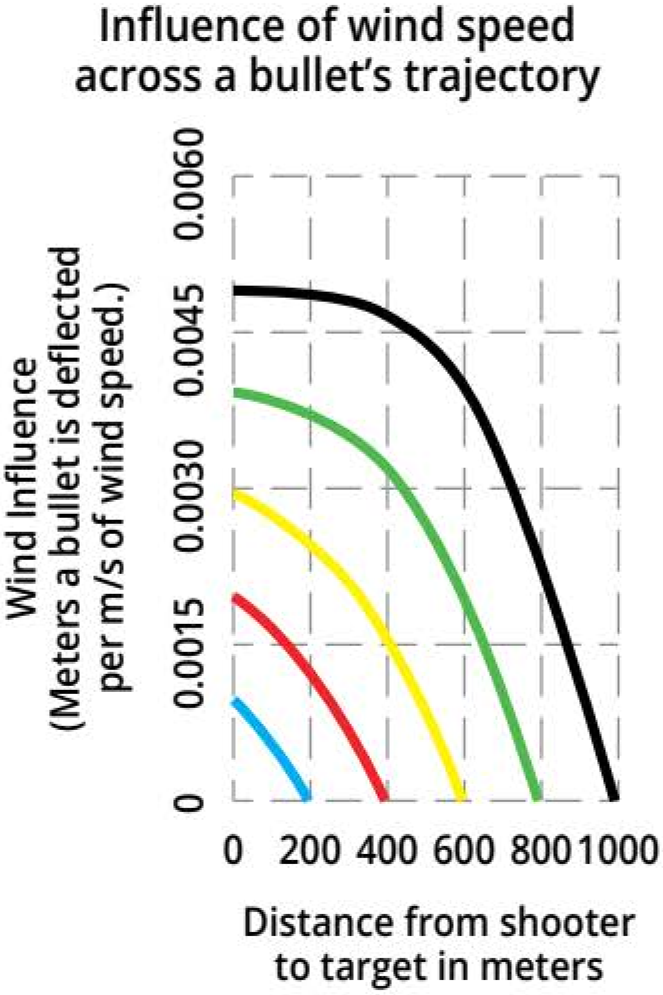

Image 148: This shows the same idea as the graph to the left in a different form. Wind deflects bullets less as bullets get closer to their target. However, this reduction is not linear; it follows a convex curve.

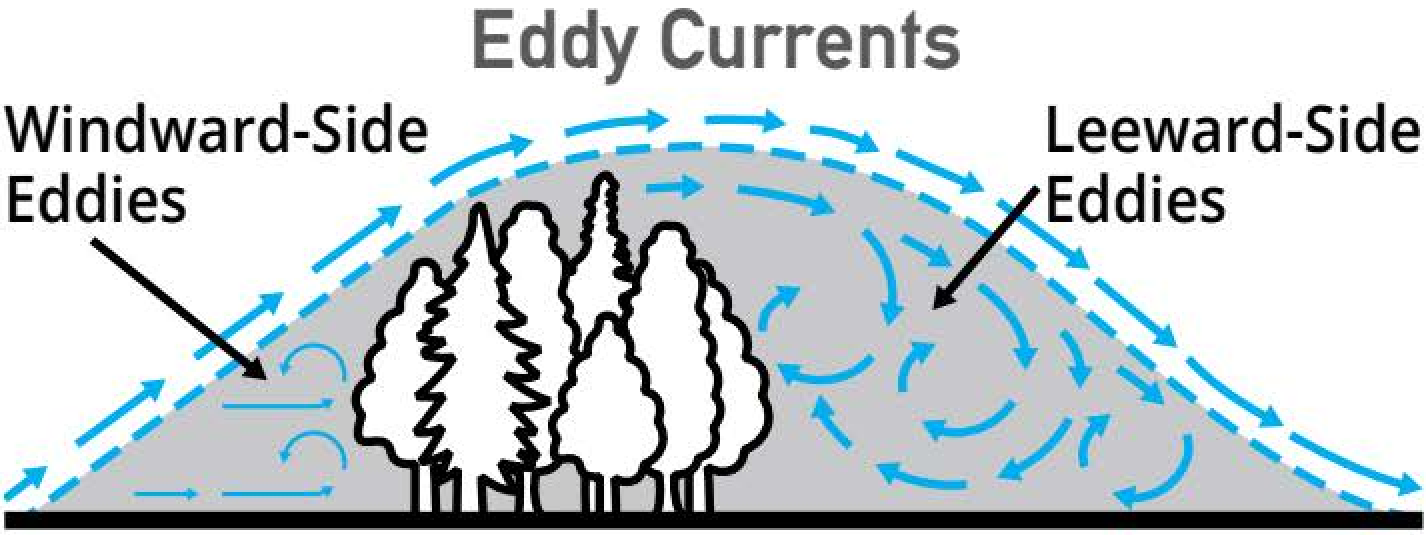

Image 149: **An eddy is a circular movement of air** that deviates from the main flow. On the windward side, where the wind directly hits the barrier, eddies form less frequently, especially when the barrier is smooth. Wind may instead move smoothly, but vertically up the barrier. However, small-scale eddies can occur if the wind is turbulent or the surface of the barrier is rough. **On the leeward side (the side with wind blowing away from it), eddies are much more prominent**. The length of the eddies formed in the wake of the barrier can extend five to fifteen times the barrier's height.

For example, assuming three sections of equal distance, the marksman can allocate the first third of the bullet's travel distance to have a weight of one-half of the weighted average equivalent crosswind (AEC), the second third to have a weight of one-third of the weighted AEC, and the last third to have a weight of one-sixth of the weighted AEC. That is:

- *½(near-third EC) + ⅓(middle-third EC) + ⅙(far-third EC) = AEC.*

A formula for only two sections may look like this:

- *⅔(near-half EC) + ⅓(far-half EC) = AEC.*

These formulas use simple, approximate fractions to make the math easy. The true fractions would change based on the distance a bullet travels and the rifle equipment used. (See Image 147, Pg. 168.)

Marksmen can also use sections of different distances with equal weight (i.e., a simple average, or mean). For example, a marksman may consider calculating the mean-average equivalent-crosswind by simple-averaging the effects of wind in the first quarter of the distance, the second quarter of the distance, and the second half of the distance with equal weight. That is:

- *⅓(first-quarter EC) + ⅓(second-quarter EC) + ⅓(second-half EC) = AEC.*

This method gets its wind readings closer to the marksman, and may be preferable if a marksman can get better wind estimates at closer locations.

A third way to section a bullet's trajectory is to avoid fractions altogether, and instead section the trajectory using natural dividers such as valleys or open areas. Then the marksman assigns a weight to each section based on their personal experience. This approach works well when a bullet travels through terrain that is unusual or has an unusual wind for some reason. However, it also requires a lot of practice shooting over different terrain, as the connection between an environmental feature and a certain kind of wind can be both subtle and dynamic. There cannot be a general rule either, as the terrain must inherently be very unusual or non-standard for this method to be superior to the aforementioned fractional-sectioning methods.

For example, valleys are notorious for channeling wind to high speeds that do not match the surrounding area. In contrast, an area surrounded by vegetation may have significantly slower winds than surrounding areas. Solid obstacles such as large walls or cliff faces can even create **eddy currents** (air moving in chaotic circles) that reverse or confuse the wind direction. (See Image 149, Pg. 169.) While single, odd trees or reversed wind flags can be ignored, a few factors together may indicate a significant reverse wind.

There are two final options to shoot accurately through multiple winds while avoiding calculations altogether. First, a marksman can simply **wait for there to be only one wind present**. This can occur if either all the winds merge into a single wind, or the wind dies entirely. (See Changing Wind over Time, Pg. 171.) Alternatively, if all winds are relatively constant and a marksman can afford to miss, they can fire a test shot and make adjustments for following shots based on the first shot's impact.

Despite the science that says otherwise, some marksmen have been taught that farther winds affect bullets more. The logic behind this is that bullets slow down as they travel, so farther winds have more time to act on a bullet per unit of distance traveled compared to closer winds. While bullets do slow down, they do not slow down enough for the effect to be stronger than the earlier deflection caused by closer winds. For example, wind in the final third of a trajectory would need to work on a bullet traveling three times slower than a wind in the first third to have an equivalent effect, At one third the speed, most bullets would become subsonic and start to tumble. (It is possible to check if a projectile tumbled by observing its impact on the target since tumbling in the air typically leads to an oblong hole on the target (a.k.a., a "keyhole.").

Another reason marksmen may believe that farther winds are stronger is that they often measure wind in enclosed spaces with no wind. This is common because people naturally seek non-windy areas to be more comfortable. With that said, **it is recommended that marksmen consider the effects of wind outside their immediate, comfortable area**.

Another flawed method of dealing with multiple winds used by some marksmen is to simply use the highest recorded wind speed. While this approach may work to some extent, it is important to recognize that a strong wind is likely not present along the entire shooting range.

15.f Changing Wind over Time

Wind is constantly changing its direction, speed, or both over time, so the wind that a marksman expects is not necessarily the wind that the bullet experiences after being shot from the rifle. This mismatch mostly occurs because of the delay between when a marksman observes the wind and when they shoot. However, **there is also a fundamental delay from the moment a marksman pulls the trigger to when the bullet travels through the air**.

Typically, changing wind is not a problem as it remains stable enough from second to second. However, there are instances when the wind changes too rapidly for any estimate to be timely, such as when gusts are common. In those cases, it is best to **measure and shoot when the wind is consistent**, rather than when it is completely calm. This is especially true where wind only experiences brief and random pauses (i.e., most places). If wind is never consistent, marksmen can take multiple measurements to calculate an average.

If the wind is changing too rapidly to measure quickly, a marksman can rely on a visual cue instead. For example, if the marksman notices that their shots consistently hit the target when the wind causes the tips of two branches to come into contact, they can time their shots and only fire when the branches touch. The only downside of using a visual cue is that they are difficult to find in the first place.

The patterns by which wind changes can be found, but are not immediately obvious. To measure a wind pattern, marksmen can create a diagram using equivalent crosswind velocity on the Y-axis and time on the X-axis. (See Image 150, Pg. 172.) Every minute or less, the marksman records the wind value. After ten minutes and ten measurements, a pattern may emerge.

With this information, marksmen can make reasonably accurate predictions about when a preferred wind is likely to occur. However, more importantly, such a diagram also illustrates the limits of the equivalent crosswind speed, or in other words what winds do not occur. This is useful because it allows marksmen to avoid shooting when a gust is likely to occur. Knowing the limits of wind speed is also useful when using a "hold-target" windage hold. (See Image 154, Pg. 177.) The most common equivalent wind

Tracking Wind Speed over Time

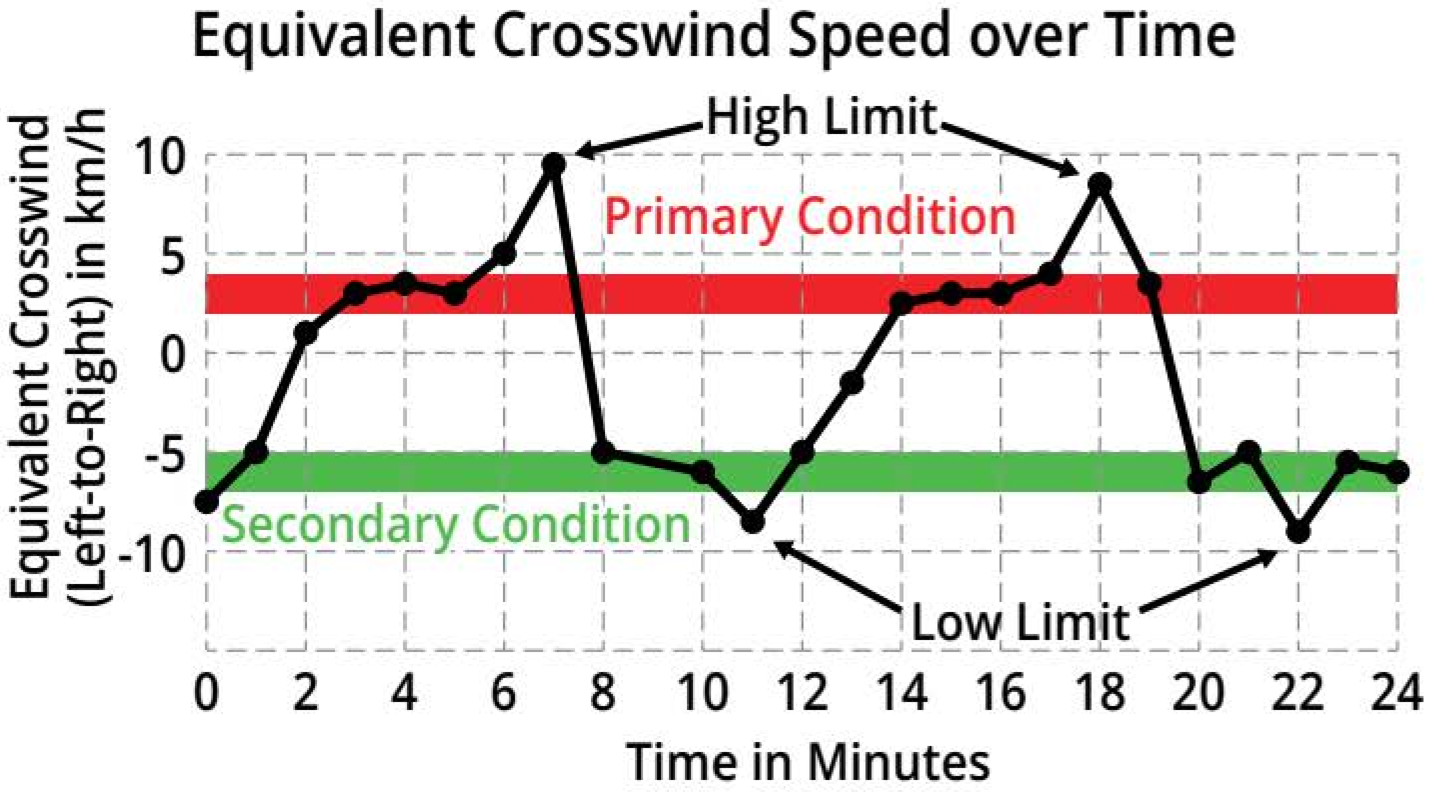

Image 150: Wind in an area and period is bounded by high and low speed limits. Also, **wind may have multiple conditions and switch between them**. This example shows two conditions. A marksman can chart wind patterns in a specific area over different times and seasons to identify local wind trends. By understanding how long wind conditions typically remain stable, the marksman can determine the optimal window to take a shot before the wind changes.

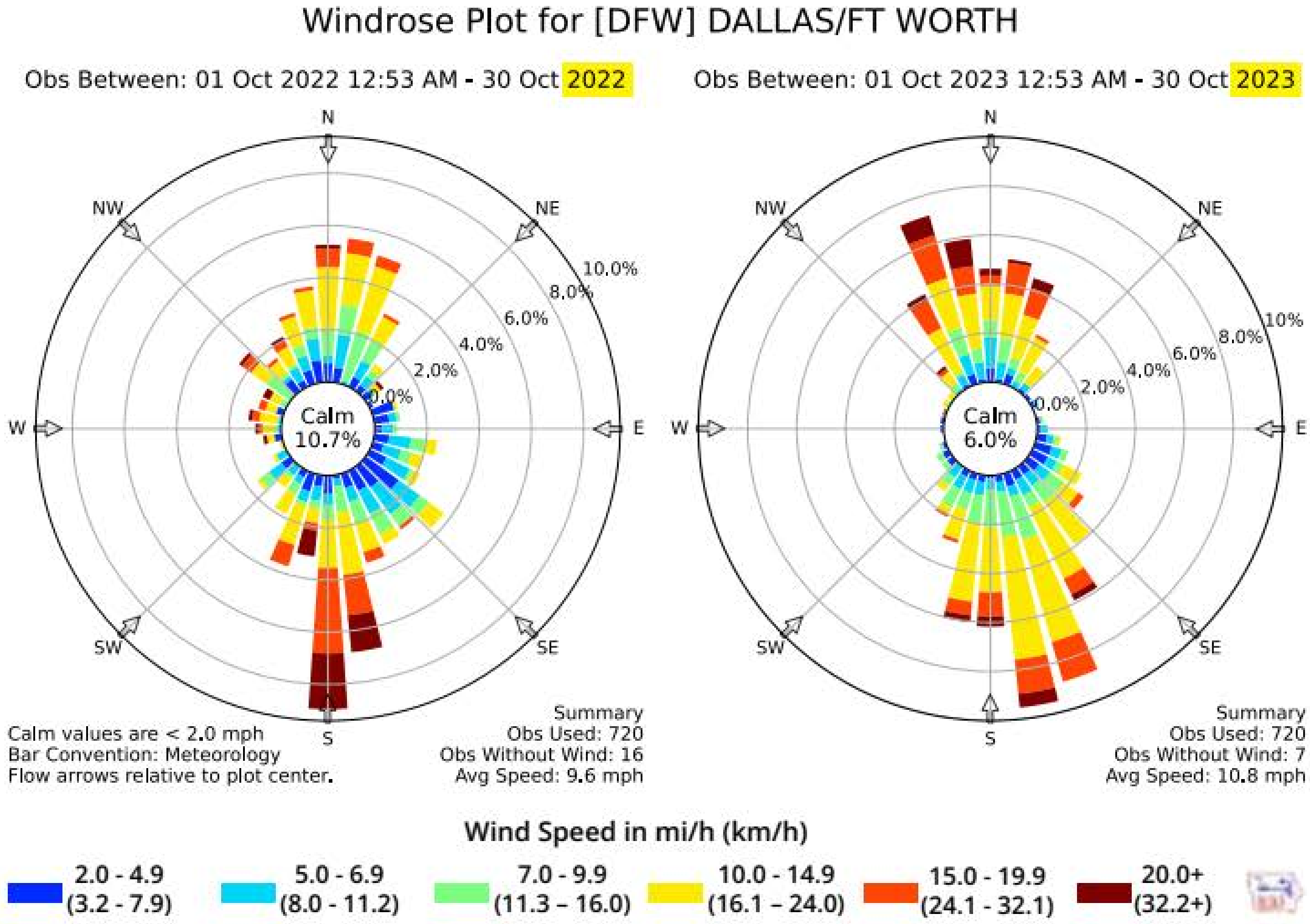

Image 151: Wind roses are circular histograms that show winds' origins during a period of time. This one for Dallas, Texas in October 2022 (left) and 2023 (right) shows that during October the wind primarily comes from the North and South.

speed is the wind's "condition." A wind can have multiple conditions. (See Image 151, Pg. 172.).

(For the statistically oriented, the equivalent crosswind speed can be modeled with a normal distribution or a multimodal normal distribution. A "condition" is the mean or mode and not technically sticky, and a "limit" is where winds become very improbable according to the standard deviation.)

15.g Windage Holds and Dials

Once the equivalent crosswind is determined, the marksman can convert it into a windage hold, which indicates which horizontal hashmark on the reticle the marksman must use as their point-of-aim. To counteract the wind's force, the marksman **must always shoot into the wind**. So, if a marksman encounters a left-to-right crosswind, they aim to the left by using a windage hashmark on the right side of the reticle.

The fact that wind from the left requires using the right side of the reticle, and vice versa, can cause confusion and errors when an assistant or spotter communicates wind information to a marksman, especially under stressful conditions. To clear up all of this confusion, it can be helpful to always add "point rifle" or "wind from" at the beginning of any communication. For example, "wind from the left, 2 mils," meaning: align a target with the 2-mil hashmark on the right side of the reticle.

Reticles can compensate for wind effects because they measure angular distance, and wind deflects bullets at an angle. (See Image 141, Pg. 163.) That is, wind deflects bullets from their original trajectory onto a new trajectory, so the windage hold is equal to the angle of that deflection. For example, a 20 km/h (12 mi/h) crosswind is 1% of the airflow that a bullet traveling at 2,000 km/h (1,240 mi/h) experiences. Therefore, the bullet may rotate approximately 1% or about 1° into the wind. In sum, countering the wind's effect can be achieved by firing the bullet at the exact opposite angular distance to cancel out the wind's angular deviation.

The amount of deflection is directly correlated to the speed of the crosswind. For example, if in an 8 km/h (5 mi/h) crosswind, a bullet would be deflected by 10 cm (2.5 in) at a distance of 100 m, a 16 km/h (10 mi/h) crosswind would deflect the bullet by 20 cm (5.1 in) at 100 m. That is, a wind that is double the power always deflects twice as much.

Rifles can be called by the amount of crosswind velocity required to deflect them by 1 mil. For example, a setup that is deflected by 1 mil by an 8 km/h (5 mi/h) crosswind would be an "8-km/h gun" or a "5-mi/h gun."

Crosswind to Windage in Mils (MOA)

Equivalent Crosswind in km/h (mi/h)	Distance to Target in m (yd)									
	100 (109)	200 (219)	300 (328)	400 (437)	500 (547)	600 (656)	700 (766)	800 (875)	900 (984)	1000 (1094)
2 (1)	0.0 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.2 (0.6)	0.2 (0.8)	0.3 (0.9)	0.3 (1.0)
5 (3)	0.1 (0.2)	0.1 (0.4)	0.2 (0.6)	0.2 (0.8)	0.3 (1.1)	0.4 (1.3)	0.5 (1.6)	0.6 (1.9)	0.7 (2.3)	0.8 (2.6)
10 (6)	0.1 (0.4)	0.2 (0.8)	0.3 (1.2)	0.5 (1.6)	0.6 (2.1)	0.8 (2.6)	0.9 (3.2)	1.1 (3.8)	1.3 (4.5)	1.5 (5.2)
15 (10)	0.1 (0.5)	0.3 (1.1)	0.5 (1.8)	0.7 (2.5)	0.9 (3.2)	1.2 (4.0)	1.4 (4.8)	1.7 (5.7)	2.0 (6.8)	2.3 (7.9)
20 (13)	0.2 (0.7)	0.4 (1.5)	0.7 (2.4)	1.0 (3.3)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	2.2 (7.6)	2.6 (9.0)	3.1 (10.5)
25 (16)	0.3 (0.9)	0.6 (1.9)	0.9 (3.0)	1.2 (4.1)	1.5 (5.3)	1.9 (6.6)	2.3 (8.0)	2.8 (9.6)	3.3 (11.3)	3.8 (13.1)
30 (19)	0.3 (1.1)	0.7 (2.3)	1.0 (3.5)	1.4 (4.9)	1.9 (6.4)	2.3 (7.9)	2.8 (9.6)	3.3 (11.5)	3.9 (13.5)	4.6 (15.7)
35 (22)	0.4 (1.3)	0.8 (2.7)	1.2 (4.1)	1.7 (5.7)	2.2 (7.4)	2.7 (9.2)	3.3 (11.2)	3.9 (13.4)	4.6 (15.8)	5.3 (18.3)
40 (25)	0.4 (1.4)	0.9 (3.0)	1.4 (4.7)	1.9 (6.6)	2.5 (8.5)	3.1 (10.6)	3.7 (12.8)	4.4 (15.3)	5.2 (18.0)	6.1 (21.0)
45 (28)	0.5 (1.6)	1.0 (3.4)	1.5 (5.3)	2.2 (7.4)	2.8 (9.5)	3.5 (11.9)	4.2 (14.4)	5.0 (17.2)	5.9 (20.3)	6.9 (23.6)
50 (31)	0.5 (1.8)	1.1 (3.8)	1.7 (5.9)	2.4 (8.2)	3.1 (10.6)	3.8 (13.2)	4.7 (16.0)	5.6 (19.1)	6.5 (22.5)	7.6 (26.2)

Image 152: This table takes the distance to the target (X-axis) and the equivalent crosswind (Y-axis), and **outputs the windage hold or dial (cell contents) in mils and MOA.** The values here are specifically for a .308 match cartridge (155-grain bullet, 43.0 grains powder). Note that the additional windage hold (e.g., for a 50 km/h (31 mi/h) wind) is almost twice as much between 900 and 1000 m (7.6 - 6.5 = **1.1**) as between 100 and 200 m (1.1 - 0.5 = **0.6**). Marksmen can also convert the hold into clicks on their scope if they are dialing for wind.

This table is only an example because equipment characteristics, such as barrel length, affect a rifle's muzzle velocity, which in turn influences the windage adjustments. In fact, elevation and windage charts require constant adjustments anyway because the correction elevation and windage holds change as a barrel experiences wear over its lifetime. Both windage and elevation tables are also **only valid for one set of environmental conditions** (e.g., temperature, altitude, etc.); however, it only takes minor changes to make a table made for one setup in one environment valid in another environment.

Ready-made charts such as this can often be found online for specific rifles and ammunition. This chart is just an example.

Actual Wind to Windage at 500 m

Wind Direction		Actual Wind Speed in km/h (mi/h)									
Degrees	O'clock	5 (3)	10 (6)	15 (9)	20 (12)	25 (16)	30 (19)	35 (22)	40 (25)	45 (28)	50 (31)
0°	12:00, 6:00	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
10°		0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.3 (1.1)	0.3 (1.1)	0.3 (1.1)	0.3 (1.1)	0.6 (2.1)	0.6 (2.1)
15°	11:30, 12:30, 5:30, 6:30	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.3 (1.1)	0.3 (1.1)	0.6 (2.1)	0.6 (2.1)	0.6 (2.1)	0.6 (2.1)	0.9 (3.2)
20°		0.1 (0.4)	0.1 (0.4)	0.3 (1.1)	0.3 (1.1)	0.6 (2.1)	0.6 (2.1)	0.9 (3.2)	0.9 (3.2)	0.9 (3.2)	1.2 (4.2)
30°	11:00, 1:00, 5:00, 7:00	0.1 (0.4)	0.3 (1.1)	0.6 (2.1)	0.6 (2.1)	0.9 (3.2)	0.9 (3.2)	1.2 (4.2)	1.2 (4.2)	1.5 (5.3)	1.5 (5.3)
40°		0.1 (0.4)	0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	0.9 (3.2)	1.2 (4.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	1.9 (6.4)
45°	10:30, 1:30, 4:30, 7:30	0.1 (0.4)	0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	1.9 (6.4)	2.2 (7.4)
50°		0.1 (0.4)	0.6 (2.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	2.2 (7.4)	2.5 (8.5)
60°	10:00, 2:00, 4:00, 8:00	0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	2.2 (7.4)	2.5 (8.5)	2.8 (9.5)
70°		0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.5 (5.3)	1.5 (5.3)	2.2 (7.4)	2.5 (8.5)	2.5 (8.5)	2.8 (9.5)
75°	2:30, 3:30, 8:30, 9:30	0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	2.2 (7.4)	2.5 (8.5)	2.8 (9.5)	3.1 (10.6)
80°		0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	2.2 (7.4)	2.5 (8.5)	2.8 (9.5)	3.1 (10.6)
90°	3:00, 9:00	0.3 (1.1)	0.6 (2.1)	0.9 (3.2)	1.2 (4.2)	1.5 (5.3)	1.9 (6.4)	2.2 (7.4)	2.5 (8.5)	2.8 (9.5)	3.1 (10.6)

Image 153: This table takes the actual horizontal wind speed (X-axis) and the wind's direction (Y-axis), and outputs the wind hold (windage) for a 500 m target. **This table is not valid at any other distance.** Also, because the Crosswind to Windage table used increments of 5 km/h, the conversion to mil (MOA) is rounded to the nearest 5 km/h.

This kind of table is useful for marksmen who only shoot at one distance. It can be made by taking a wind value conversion table (See Image 140, Pg. 161.), and converting the cell contents (equivalent crosswind) into a corresponding windage by using a single column of a windage table (See Image 152, Pg. 174.). In fact, marksmen can drastically **simplify the table even further** by eliminating columns and rows for uncommon winds that they do not expect to see where they are shooting. If a marksman is dialing their windage, they can go one step further and convert windage hold into the number of windage dial clicks.

Ready-made charts such as this can often be found online for specific rifles and ammunition. This chart is just an example.

Doubling the distance to the target, however, more than doubles the deflection. This is because bullets slow down as they travel, so a crosswind has more than twice as much time to act on a bullet at twice the distance. (That being said, when bullet speed is relatively stable, for example before 300 m or yd, the angle of wind deflection can be treated as if it were linear because wind speed is an estimate anyway.)

A wind meter and a ballistic calculator are very helpful to determine the necessary windage hold to counteract a crosswind. (See Meters, Pg. 216.) (See Ballistic Calculators, Pg. 221.) However, the traditional method is simple trial and error. That is, a marksman fires into a well-measured crosswind at targets of various distances and measures how far sideways the bullet was deflected. The marksman can then construct a table where the X axis is the distance to the target, the Y axis is the wind speed, and each cell has the angle of deflection (i.e., the windage hold). Although these tables take considerable time to create for an individual marksman and their specific equipment, generic wind tables are readily available online. (See Image 152, Pg. 174.)

Wind can gust, die down, or even switch directions. To account for these swift changes in wind, **windage is not typically adjusted by dialing turrets**. Instead, marksmen use the faster approach of holding the reticle to the side and using an off-center hashmark as their point-of-aim.

However, there are a few exceptions to not dialing for wind. First, in the case of a second-focal plane scope, the reticle hashmarks only represent whole-number angular measurements at specific magnifications. (See Image 119, Pg. 137.) If the marksman wants to use an arbitrary magnification setting, they cannot utilize the reticle to hold for wind. Nevertheless, this scenario is not particularly common, as marksmen often only magnify to a zoom level where the clicks on the turret align with the reticle hashmarks.

Another exception to not dialing for wind includes when marksmen take multiple shots at a target in relatively consistent wind conditions; then they can adjust the windage dial so that the center of the reticle aligns with the center of the target when the wind blows at its most common speed. That is, they can dial to the wind's primary condition. (See Image 150, Pg. 172.) Furthermore, marksmen who engage in shooting at extreme distances can employ both dialing and holding techniques to compensate for shooting into extremely strong winds, as relying solely on one method could be insufficient.

There are also techniques to compensate for wind without using reticle hashmarks nor dialing. The simplest technique is to "**hold target**" left or

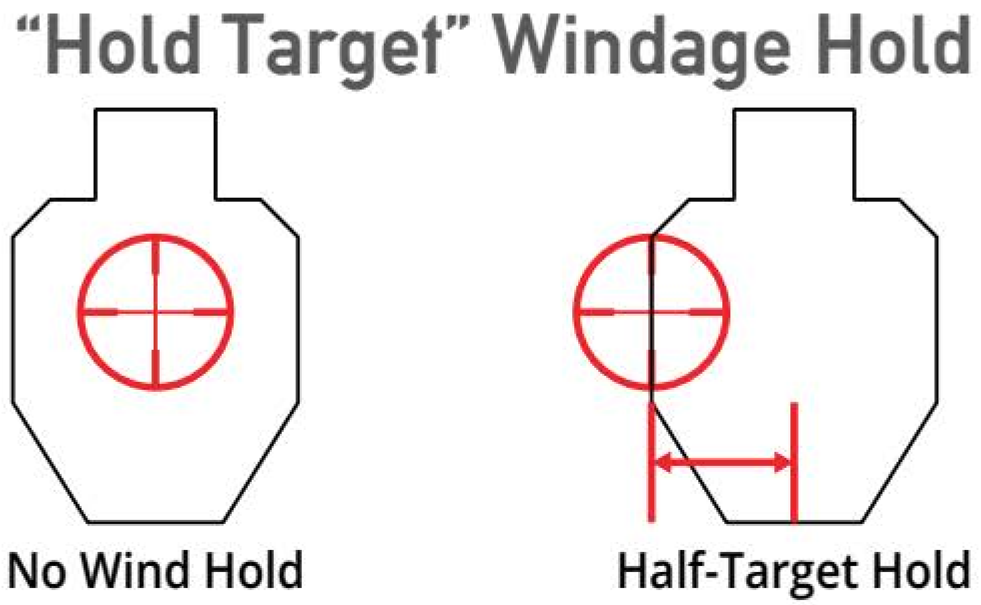

Image 154: If the direction of the wind is known, a marksman can use a half-target hold, where the marksman aims into the wind at the maximum edge of the target. Thereby, **the wind has twice as much distance to blow the bullet** before the wind deflects the bullet completely off the target.

right. (See Image 154, Pg. 177.) This technique points the center of the reticle at the maximum left edge of the target if the wind blows from left to right, and the maximum right edge if the wind blows from right to left. The logic behind this is that a constant crosswind only pushes a bullet in one direction, and so it can only push the bullet from the edge towards the center. Therefore, if the wind weakens, a bullet hits the edge of the target, and if the wind remains strong, it pushes the bullet toward the opposite side of the target. Either way, the bullet hits the target.

After the first shot, this technique can also be used to refine a marksman’s aim. For example, if a bullet aimed at one edge is blown across the target and hits the opposite edge, the marksman can adjust their aim by half of a target’s width off the edge opposite of the impact to hit the center of the target.

Another technique that works irrespective of the wind is **for the marksman to change their position**. If there is a 90° crosswind, the marksman can rotate their shooting position 90° around the target to turn the crosswind into a headwind or tailwind. Alternatively, the marksman can try to get closer to the target. At a closer distance, bullets are less affected by many external factors including wind.

15.h Converting a Wind to a Windage Hold (Summary)

Converting wind to a windage hold is a complicated process. In fact, tournament competitors often arrive hours before a competition to assess the wind conditions on the range. Prepared marksmen may even study maps and pictures to determine the typical wind patterns, and understand any potential atypical patterns and obstacles that could alter the prevailing wind's direction and strength. Bowl-shaped areas, in particular, can create non-standard wind patterns, requiring extra preparation. Therefore to help simplify the process, the above section on determining a windage hold is summarized here:

1) **Measure the wind at a specific location.** This can come from an electronic tool or through an estimate. (See Wind Estimation, Pg. 178.)
    - **a)** If the wind changes over time, wait for the best wind. (See Changing Wind over Time, Pg. 171.)
    - **b)** If shooting near any cliffs or mountains, consider the effects of a vertical wind component. (See Vertical-Wind Deflection, Pg. 163.)
    - **c)** If shooting long or over a valley, consider the wind gradient and add to the measured or estimated wind speed. (See Wind Gradient, Pg. 164.)
    - **d)** If there are multiple winds, divide the range into sections and measure the wind in each section. (See Multiple Winds over Distance, Pg. 167.)

2) **Convert the actual wind into the equivalent crosswind** using a wind-value table. (See Wind Value, Pg. 159.) (See Image 140, Pg. 161.)
    - **a)** If shooting at a long range, combine the equivalent crosswinds at different locations into an average equivalent crosswind for the bullet's entire trajectory. (See Multiple Winds over Distance, Pg. 167.)

3) **Convert the equivalent crosswind into a windage hold** using a windage-hold table. (See Windage Holds and Dials, Pg. 173.) (See Image 152, Pg. 174.)
    - **a)** If shooting at one distance, combine a wind-value table and a windage table into a wind-to-windage table. (See Image 153, Pg. 175.)

16. Wind Estimation

Predicting wind is the most challenging aspect of shooting because wind is invisible and is constantly changing. And while electronic wind meters are extremely accurate, they can only measure the wind speed from the marksman's position (and they need batteries). Therefore, when shooting on a range (besides high-tech ranges with remote electronic wind meters), wind speed is not measured, but rather it is estimated. Marksmen can estimate wind by observing certain indications in the air, such as flags, surrounding vegetation, or mirages. When estimating, marksmen must **be bold** with their estimates, as wind speed is most commonly underestimated.

To improve accuracy, multiple people, such as a marksman-spotter team, can each **make independent estimates and then average them.** A group's average tends to be more accurate than a single individual's guess.

Marksmen can also enhance their wind estimation skills through training. For example, they can make estimates and compare them to readings from a wind meter. Some marksmen enjoy estimating wind as a pastime, for example, while walking their dog. With practice, a marksman can improve the accuracy of their wind speed estimates based on any cues they see. They can also discover more wind cues, enabling them to consider more information.

That said, the practice of estimating wind using environmental cues may soon become obsolete due to technological advancements, much like how laser rangefinders replaced manual distance estimation. For example, ZX Lidars' product, the ZXTM, can measure wind speed and direction with a high level of precision, up to a distance of 550 m (602 yd). Today, its total adoption is only hindered by its weight of 90 kg (198 lb), but its future generations will undoubtedly be smaller and much more portable.

16.a Flags and Vanes

Flags and vanes (devices that rotate to face the wind) are useful tools for estimating wind conditions at a distance from a marksman, as they can show both wind speed and direction.

Streamer flags (i.e., normal flags) are simple strips of cloth or plastic that flutter in the wind. Flags point opposite the wind's direction, with a raised flag indicating strong wind and a hanging flag suggesting light or no wind. They are often brightly colored for visibility. Streamer flags can indicate wind direction, but they are not reliable for showing wind speed.

Wind cones (a.k.a., windsocks or wind sleeves) are also made of fabric and flutter in the wind; but in contrast to regular flags, they are cone-shaped fabric tubes that catch the wind and point in the direction it is blowing. They are often designed with sections that indicate the wind speed by inflating at specific speeds. (See Image 155, Pg. 180.)

Vanes (a.k.a., wind vanes or weathervanes) are mounted on a pivot, and they consist of a tail and a pointer. The tail catches the wind, while the pointer indicates the wind direction. Pinwheel vanes are a kind of vane that have a small pinwheel or propeller attached to their vane. The direction

Wind Flags and Wind Cones

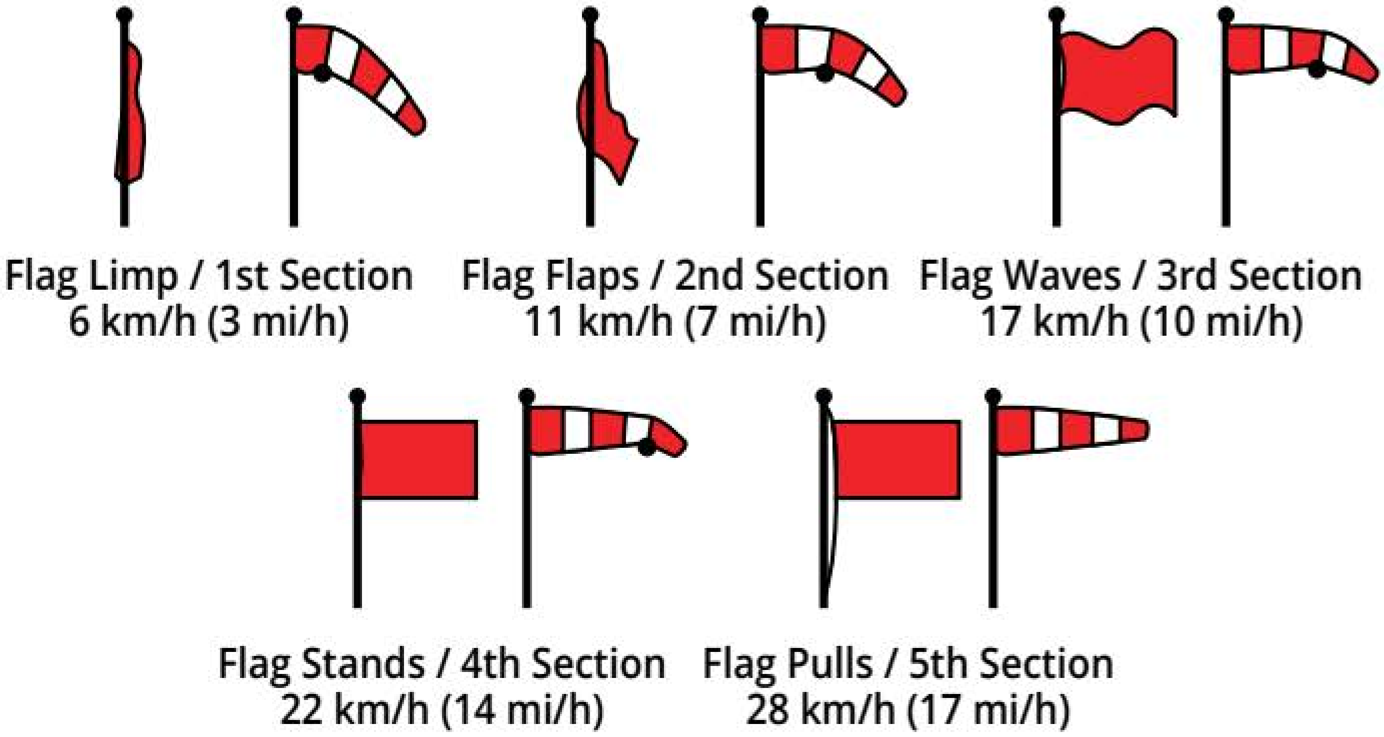
Flag Limp / 1st Section
6 km/h (3 mi/h)
Flag Flaps / 2nd Section
11 km/h (7 mi/h)
Flag Waves / 3rd Section
17 km/h (10 mi/h)
Flag Stands / 4th Section
22 km/h (14 mi/h)
Flag Pulls / 5th Section
28 km/h (17 mi/h)

Image 155: A wind flag can either be a regular, streamer flag (left) or a special tool called a "wind cone" (right). Wind cones have hollow, stripped sections that represent 3 knots each. So, the second section extends at 6 knots, the third at 9, etc. (A knot is an imperial unit of distance equal to 1.14 miles or 1.85 kilometers.)

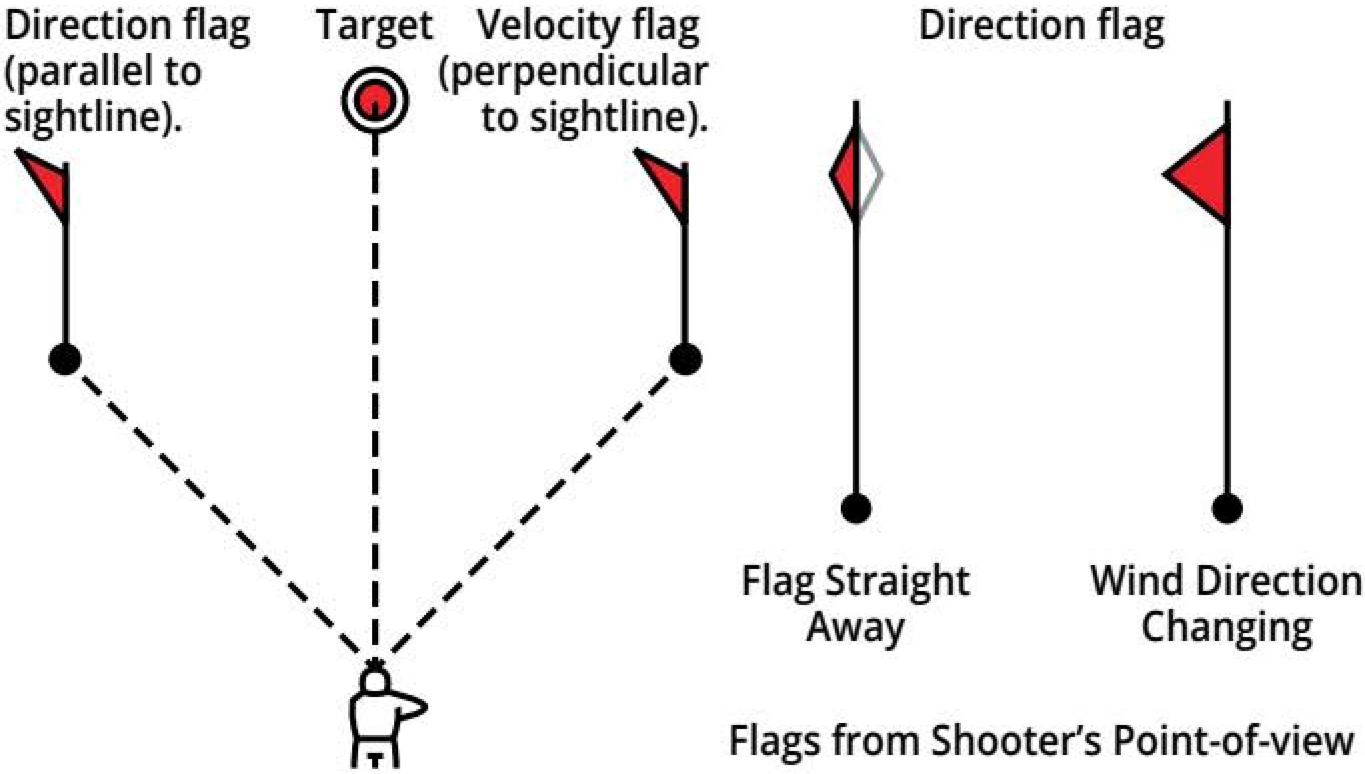
Direction flag (parallel to sightline).
Target
Velocity flag (perpendicular to sightline).
Direction flag
Flag Straight Away
Wind Direction Changing
Flags from Shooter's Point-of-view

Image 156: A marksman can use **multiple wind flags** to better read the wind. This is best done by placing two flags, one at 45 degrees forward left and one at 45 degrees forward right. Then, no matter which direction the wind blows from, one flag is more parallel to the marksman, and one is more perpendicular. The parallel flag is easier to read wind direction from, and is the direction flag (left). The perpendicular flag is easier to read wind speed from, and is the speed flag (first diagram above).

Wind Vanes

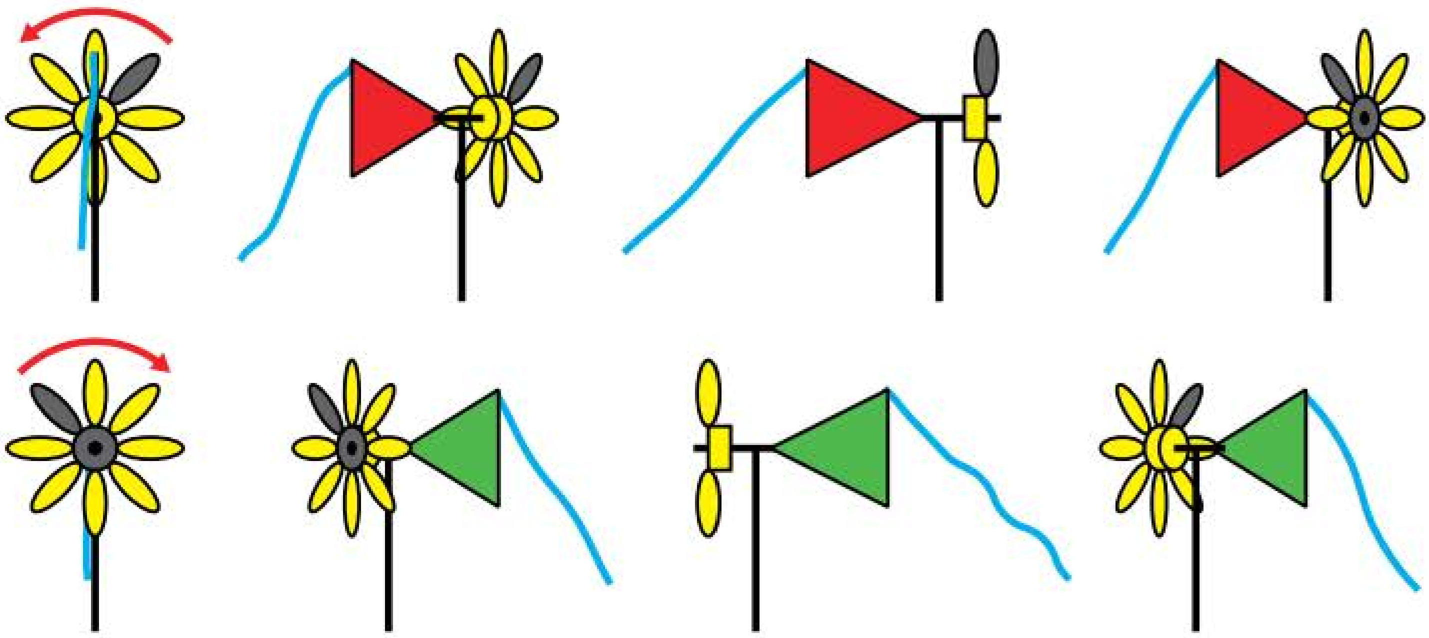

Image 157: A wind vane is a stick mounted on a swivel that points in the direction of the wind. Some wind vanes may have attached propellers that can also tell the wind speed. This is made easier by coloring one blade a different color so that the speed of rotation is more obvious. This example also has a few other indicators, such as a tail painted with two colors to more easily know which direction the vane is slanted towards, and also a ribbon tail that flows in the wind. Wind vanes are **cheap and easy to transport**, so a marksman can stick many into the ground.

of the pinwheel indicates wind direction, and the speed at which it spins provides an indication of wind speed. (See Image 157, Pg. 181.)

While streamer and vane flags are useful, marksmen often do not know precisely how one reacts to wind. Even two flags or vanes of the same type may perform differently depending on how they are mounted, their age, and the environmental conditions in which they operate. Therefore, it is important that marksmen have experience using their particular devices And novice marksmen may have to rely on backup measurements from other devices or techniques.

Marksmen can enhance the utility of flags by using multiple flags simultaneously. For example, a marksman can place a flag 45° forward left and 45° forward right of their shooting location. (The two flags form a 90° angle with the marksman.) (See Image 156, Pg. 180.) Since two identical flags respond identically to the same wind conditions, the marksman can effectively gather information from two different viewpoints (one for each flag). The flag that points towards or away from the marksman can provide more precise information on wind direction, while the one perpendicular to the marksman gives a more accurate representation of wind speed.

Multiple flags can also be useful when placed on either side (left and right) of a shooting range. Then regardless of whether a wind blows left-to-right or right-to-left, at least one flag is always upwind, showing information about the wind entering the shooting range. In contrast, downwind flags are not as useful because they only describe winds that have already left the shooting range.

Of course, marksmen are not limited to a specific number of flags or vanes and can use many. Additional flags help gather information in challenging areas, such as terrain gaps with gusts. However, it is important to note that each reading from a flag takes time, during which wind conditions can change.

16.b Vegetation

In instances where flags are not available, the surrounding vegetation can be used to estimate wind. The effects of wind on vegetation vary depending on the intensity of the wind. While the impact may not be as distinct or as precise as with specifically designed wind flags, some general guidelines from the Beaufort wind scale can be useful (See Image 158, Pg. 183.):

- 0 to 5 km/h (0 to 3 mi/h) : Wind is barely noticeable.
- 5 to 10 km/h (3 to 5 mi/h): Leaves slightly sway.
- 10 to 15 km/h (5 to 8 mi/h): Leaves are in continuous motion.
- 15 to 20 km/h (8 to 12 mi/h): Stray leaves become airborne.
- 20 to 25 km/h (12 to 15 mi/h): Thin tree trunks slightly bend.
- 25 to 30 km/h (15 to 20 mi/h): Thin tree trunks bend significantly.
- 30 to 40 km/h (20 to 25 mi/h): Thick tree trunks slightly bend.

Although it is clear that these are estimations, the accuracy of these guidelines or any guidelines is actually worse than it may appear. This is because when a guide mentions “thin tree trunks sway,” each word can have a completely different meaning depending on the tree, the location, and the marksman. This is because different trees and leaves have varying weights and structures, and react to wind accordingly. So, an expert marksman who becomes skilled at reading wind in North America may not be as accurate in other parts of the world or even in different states with different vegetation.

That being said, any estimate is better than no estimate. And marksmen can become extremely accurate if they practice correlating the wind speed with the wind’s effect on local vegetation in a specific location. Some expert marksmen keep notebooks filled with information on how local vegetation reacts to wind for later reference, and can be specific enough to reference the reaction of individual trees. For example, two branches may touch on an oak tree in their backyard when the wind is 21 km/h (13 mi/h).

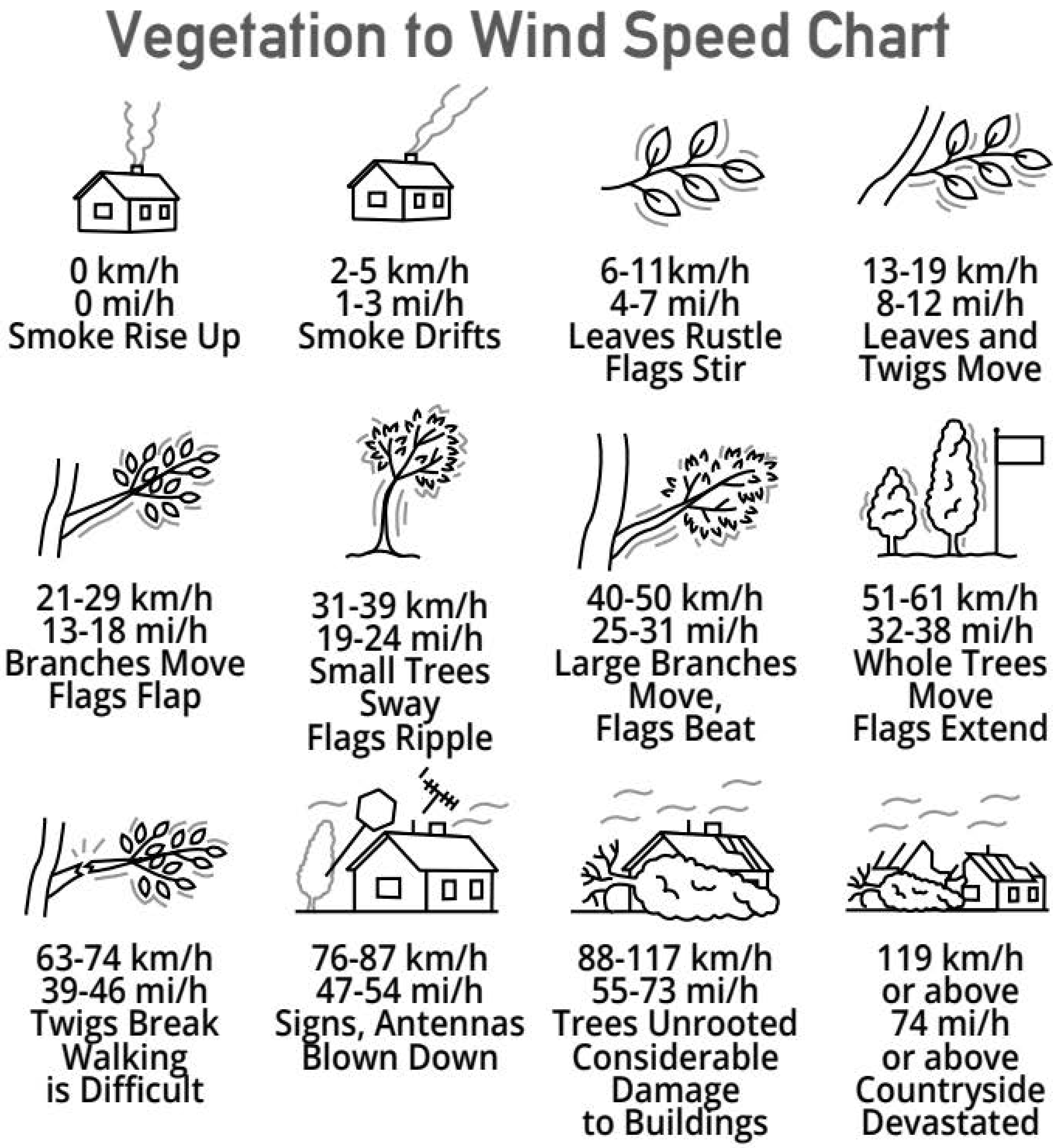
Vegetation to Wind Speed Chart
0 km/h
0 mi/h
Smoke Rise Up
2-5 km/h
1-3 mi/h
Smoke Drifts
6-11km/h
4-7 mi/h
Leaves Rustle
Flags Stir
13-19 km/h
8-12 mi/h
Leaves and
Twigs Move
21-29 km/h
13-18 mi/h
Branches Move
Flags Flap
31-39 km/h
19-24 mi/h
Small Trees
Sway
Flags Ripple
40-50 km/h
25-31 mi/h
Large Branches
Move,
Flags Beat
51-61 km/h
32-38 mi/h
Whole Trees
Move
Flags Extend
63-74 km/h
39-46 mi/h
Twigs Break
Walking
is Difficult
76-87 km/h
47-54 mi/h
Signs, Antennas
Blown Down
88-117 km/h
55-73 mi/h
Trees Unrooted
Considerable
Damage
to Buildings
119 km/h
or above
74 mi/h
or above
Countryside
Devastated

Image 158: Charts that convert environmental cues to wind speed are called "Beaufort scales." **Beaufort scales are not exact** because vegetation of different locations responds differently to different winds. They are also not subjective, as what one marksman may consider a "small" tree or a "large" branch may differ from another marksman's opinion. Therefore, for maximum accuracy, marksmen make their own scales for the specific locations they shoot on for later reference.

Another wind estimation method is known as the **divide-by method**. Here, the marksman either drops a leaf, observes a falling leaf, or looks at a string or flag along the path to the target. The marksman estimates the angle at which the object is falling or hanging and then divides that angle by 2.5 if using km/h, and by 4 if using mi/h. The resulting number is the estimated wind speed. For example, a leaf that falls at a 45° angle. 45 divided by 2.5 equals 18. So, the estimated wind speed is 18 km/h (11.2 mi/h).

The location from which the wind is estimated makes a significant difference for whether it can be generalized to the whole range. Gaps between

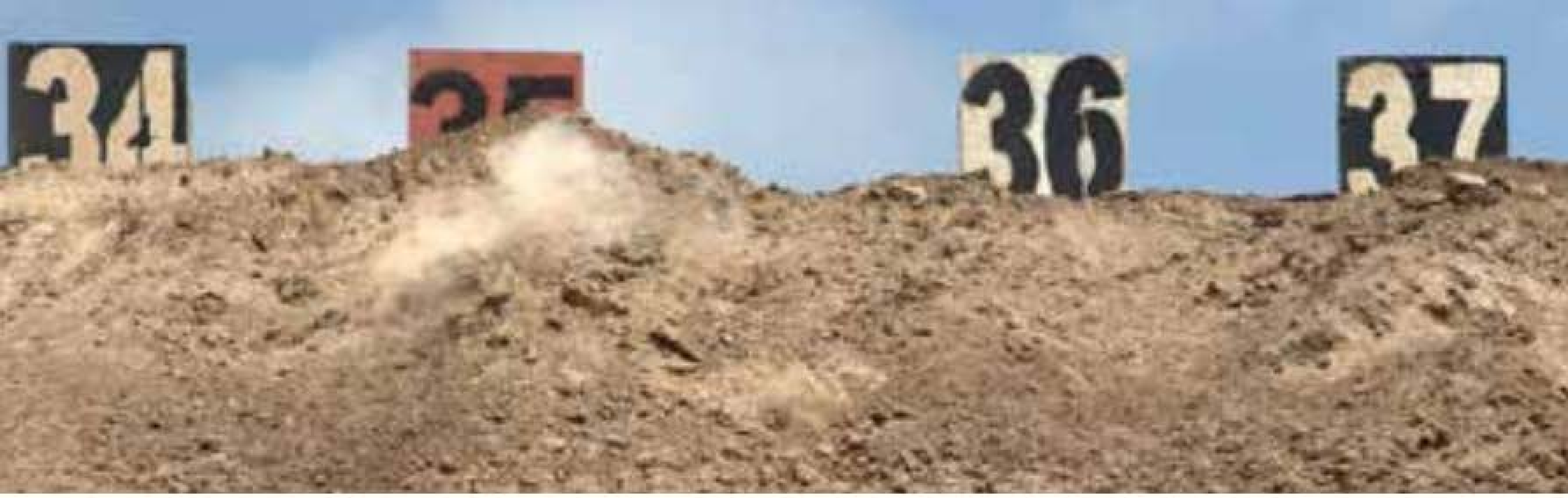

Image 159: This is a **shooting berm**, a raised strip of dirt behind shooting targets. It serves as a backstop to stop bullets from going further. The numbers indicate a shooting lane. The puff of dust under the "35" sign starts on the left (thinner) and is being pushed right (thicker) by the wind. While **impacted dirt-dust** is a consistent wind indicator, it only occurs behind the target, where the wind does not necessarily match the wind on the rest of the shooting range.

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hard structures, such as valleys or tree groves, are noticeably windier than the surrounding areas, even if they seem calm. However, if wind from a gap is parallel to the marksman, it is a headwind or tailwind. Those have little impact on bullets and can be disregarded. Wind can even become erratic when it spills over the tops of trees and swirls back (known as an eddy current). This swirling or eddying can deceive the marksman because an eddy wind moves branches without indicating a specific direction. (See Image 149, Pg. 169.)

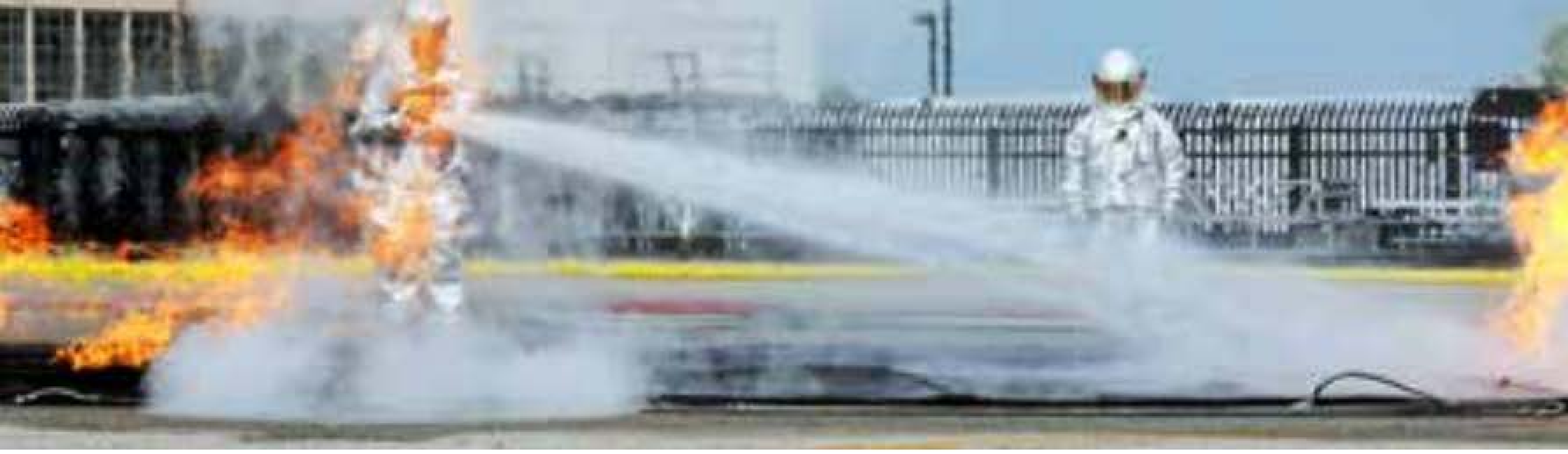
Marksmen can also calibrate their wind calls by observing the **dust** created when a bullet hits a dry berm. (See Image 153, Pg. 175.) In competition, an astute marksman waits for others to shoot into the backstop and reads the dust generated by their shots to calibrate their own estimates.

16.c Mirage

Mirage is an optical distortion whereupon objects appear wavy due to fluctuating air temperatures. This happens when different areas of air have varying temperatures and densities. Since light bends differently through air of different densities, pockets of hot and cold air create the wavy visual effect effect known as a "mirage."

Mirages appear as vertical lines because hot air rises straight up, creating columns between cooler, denser air. As the sun heats the ground, a layer of hot air forms just above the surface, beneath the cooler air. The intense heat at ground level causes the air to move quickly and shimmer, producing wavy lines that resemble moving water or oil.

Certain conditions are more prone to creating a mirage than others. For example, sunnier days in open areas cause the ground to heat up faster, and



Simple Mirage

Image 160: Firefighters, assigned to the Ohio National Guard's 180th Fighter Wing, extinguish controlled fires. Swanton, Ohio in Swanton, OH, 19 May 2020. The firefighter on the left is **obscured by mirage,** while the firefighter on the right is in the clear. Mirage is difficult to capture in a still image, which is why these images are of intense flames. However, even hot rocks can create moving mirage.

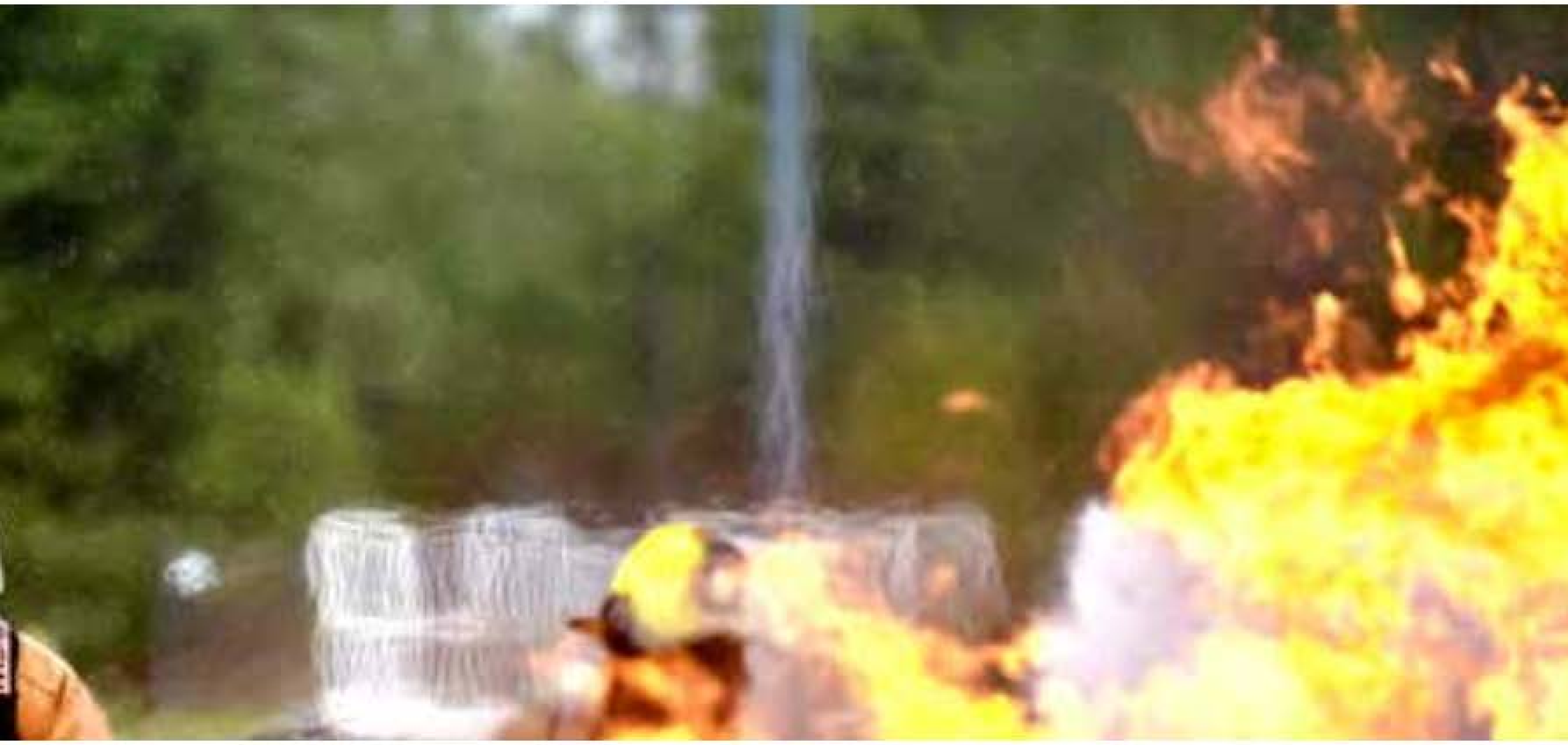


Image 161: This image shows how mirage forms **vertical columns**. Note the pole centered in the image, and how the mirage forms vertical streaks on it.

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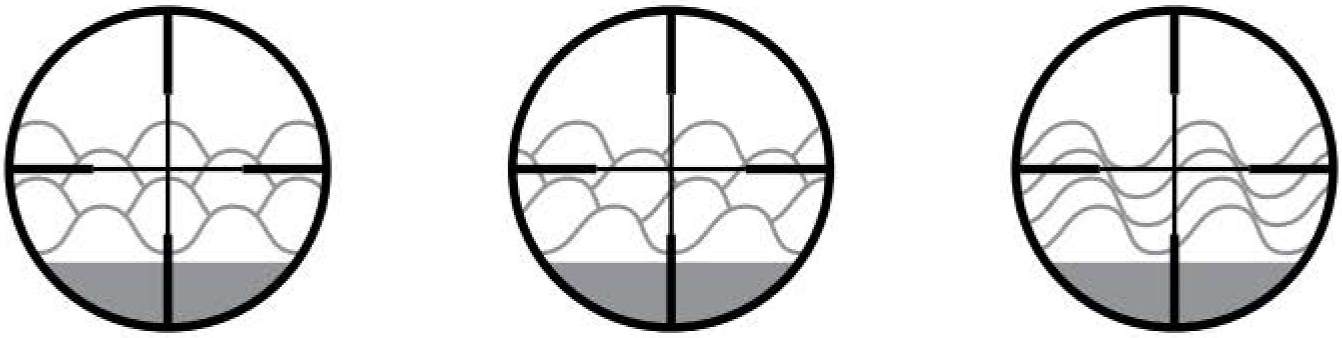
higher humidity prolongs the cold air's coolness. Since mirage depends on relative temperature rather than absolute temperature, it exists universally. Even snowy mountains experience mirage.

The fact that mirage forms alternating, vertical columns is very important. When wind blows mirage, it blows the top farther than the bottom making the columns bend over at an angle. (See Wind Gradient, Pg. 164.) Faster winds blow the columns of mirage over at a steeper angle. Therefore, a skilled marksman can infer wind speed by reading the angle of the mirage. (See Image 162, Pg. 186.) However, this cannot be done beyond approximately

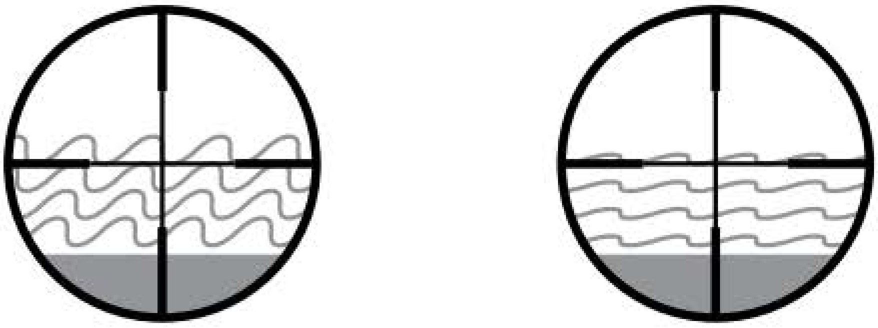
Mirage in Wind



0 Wind:
Boiling

1-5 km/h (1-3 mi/h)
Leaning

6-10 km/h (4-6 mi/h)
Flowing Gently



11-15 km/h (7-9 mi/h)
Flowing Rapidly

16-20 km/h (10-12) mi/h
Slick

Image 162: Mirage moves with the wind: the stronger the wind, the steeper and faster the mirage appears to flow. Although mirage itself behaves consistently at any given wind speed, **every marksman interprets mirage differently**. Therefore, to interpret mirage and correlate it with wind speed, a marksman must practice observing real mirage in the field and determine how it appears to them.

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15 km/h (9.3 mi/h) because wind faster than that merges the pockets of hot and cold air, thereby removing the mirage effect.

Here are some rough estimates of wind speed based on mirage:

▸ 0° (boiling): 0-1 km/h	(0-1 mi/h)	
▸ 30° mirage (leaning):	2-5 km/h	(1-3 mi/h)
▸ 45° mirage (flowing):	6-10 km/h	(4-6 mi/h)
▸ 90° mirage (rapid):	11-15 km/h	(7-9 mi/h)
▸ Slick or scrambled mirage:	16-20 km/h	(10-12 mi/h)
▸ No mirage in ideal conditions:	21+ km/h	(13+ mi/h)

The pattern of mirage can vary in both intensity and direction. Weak mirage appears as faint lines visible only through a scope, while strong mirage with clearly separated columns can be so severe that even the bullet holes on a target become difficult to see. Occasionally, when various temperature layers are present, multiple mirages may blend together. The strength of a mirage indicates nothing about the wind; wind speed can only be inferred from the mirage's angle.

Compared to flags, mirage is a more valuable indicator because it occurs **directly within the air that a bullet travels through**. Marksmen are best served by looking at a mirage that is either close to the marksman or at the midpoint of a bullet's trajectory because closer winds affect a bullet's trajectory more than farther winds. (See Image 147, Pg. 168.) Mirage at the target is only useful if it represents wind across the bullet's entire trajectory. Additionally, mirage responds instantaneously to sudden gusts because mirage is made of the air itself.

Mirage is easier to see where two contrasting surfaces meet, such as a bright white piece of paper against a dark background. To observe a strong mirage in nature, a marksman can seek a sunlit rock in front of a contrasting background such as a shaded treeline. Usually, mirage is observed at a low magnification setting since zooming too far loses the macro pattern of vertical lines when viewing a weaker mirage. However, if intense lines are present, marksmen can zoom in on a contrasting edge to observe the mirage's angle.

Even when a mirage is correctly observed, there is an incredibly rare occurrence known as a false mirage where the mirage appears to flow into the wind instead of away from it. This phenomenon happens when the wind encounters a solid object, such as a group of trees, causing the wind to spin in a descending arc against the object's surface (i.e., an eddy). (See Image 149, Pg. 169.) When this arc reverses direction, it essentially creates a reverse wind. If a mirage is observed in this reverse wind, it would indicate a wind direction contrary to the prevailing wind in the surrounding area. While eddies themselves are not uncommon, it is unusual for marksmen to be firing very close to large, solid objects that might be capable of creating eddies.

17. Climate

Climate refers to the characteristics of the air, including air density (which depends on pressure, temperature, and humidity) and precipitation. When bullets travel through the air, these characteristics influence the bullets' trajectories. Also, changes in air density change how light refracts, and can thereby interfere with a marksman's sight picture.

Given the complexity of the interactions between a climate and a bullet's trajectory, one may ask how marksmen managed to compensate for changes in climate before the age of calculators and computers. The short answer is that they didn't; marksmen would always re-zero their rifles and scopes whenever they encountered a new climate. (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.) They also didn't shoot as far, and so didn't need to account for as many variables in the first place.

17.a Temperature

Scientifically, temperature is a physical quantity which describes how quickly molecules are moving in a material. In more understandable terms, hotter objects contain more heat energy.

This increase in temperature has three effects that are relevant to shooting. First, hotter air is less dense than colder air. This is because the molecules are moving faster with more energy, and so bounce off each other with more force. This fact has implications for air density. (See Air Density, Pg. 189.)

The second effect is an increase in the speed of sound. Temperature is by far the most important factor that determines the speed of sound. The speed of sound is proportional to the square root of the absolute temperature, giving an increase of about 0.6 m/s per 1°C (1.1 ft/s per 1°F) at normal, outdoor temperatures. Bullets are designed to be the most stable when they travel at supersonic speeds, and that stability can quickly deteriorate once a bullet travels through transonic speeds into subsonic speeds. Therefore in hotter air, bullets become unstable at higher velocities (i.e., sooner in the trajectory).

The third major effect is how temperature affects gunpowder. Gunpowder is a chemical compound that burns into a gas after reaching a certain temperature. The chemical reaction of gunpowder creates a set amount of energy. Therefore, colder gunpowder explodes into a colder gas, and hotter gunpowder into a hotter gas. As mentioned, hotter gas is less dense than colder gas at the same pressure; therefore, hotter gas exerts more pressure at the same density. Given that the bore confines the gas to a set density, hotter gas then exerts more pressure on bullets in the bore than colder gas does. More pressure means higher muzzle velocity; so in sum, there is a direct relationship between the temperature of gunpowder and a bullet's muzzle velocity.

The relationship between gunpowder temperature and muzzle velocity isn't exactly linear, but it is close enough that it can be treated as such. For most rifles, raising the powder temperature by 1°C increases the muzzle velocity by about 0.5 to 1 m/s. Similarly, increasing the powder temperature by 1°F increases the muzzle velocity by about 1 to 2 ft/s.

This temperature effect usually isn't a major concern, especially before 300 m or yd. However, it can become significant in certain situations. For example, if an extreme-long-range marksman zeros their rifle on a cold winter morning but later uses it on a hot summer afternoon, that difference in temperature can impact performance. A rifle might rise about 0.2 mils (0.7 MOA) more at 300 m or yd, 1 mil (3.4 MOA) more at 1000 m or yd, and exponentially more thereafter if the muzzle velocity may increase by 3% due to a temperature difference of 40°C (72°F).

Again, all of these calculations are approximations because the chain of events (i.e., an increase in temperature, to greater chamber pressure, to a higher muzzle velocity, to decreased bullet-drop) is highly dependent on the specific rifle and ammunition in question. Also, bullet-drop is related to the time a bullet spends in the air before hitting the target, and that variable's relation to muzzle velocity is not straightforward. Therefore, exact calculations require the aid of ammunition-temperature versus muzzle-velocity calculators that can account for specific bullets and gunpowders. The best estimates may also require a bit of trial and error to dial-in estimates to specific equipment.

Of course, the simple answer is to **always shoot ammunition at the temperature it was zeroed with**. This can be done by shooting in a similar climate, or by warming (or cooling) ammunition before shooting it.

But marksmen must also not allow ammunition to heat up too much during a shooting session. Ammunition must be stored out of direct sunlight, not just as a safety measure, but also to keep it more accurate. Additionally, rifles must be able to cool down enough, and marksmen fire quickly enough so that rifle cartridges cannot absorb extra heat from the rifle. In fact, a primary purpose of brass casings is to absorb heat when fired, allowing that heat to be expelled as the casings are ejected, thereby ensuring that subsequent rounds remain cooler.

17.b Air Density

Bullets do not follow a perfect parabolic arc due to gravity because they encounter air resistance along the way. As a bullet travels, it hits air molecules and must push them aside. To push away the air molecules, the bullet must transfer some of its forward momentum to the air, which prevents the bullet from retaining that momentum to move itself forward. In denser air, there are more molecules to push through, increasing air resistance. Therefore, higher air density causes bullets to move slower and drop sooner.

To measure air density, an observer must consider the three climatic factors influencing air density: **air pressure, temperature, and humidity**. (Notably, altitude is only relevant insofar as it changes these three.) Before computers, these values were challenging to translate into a change in

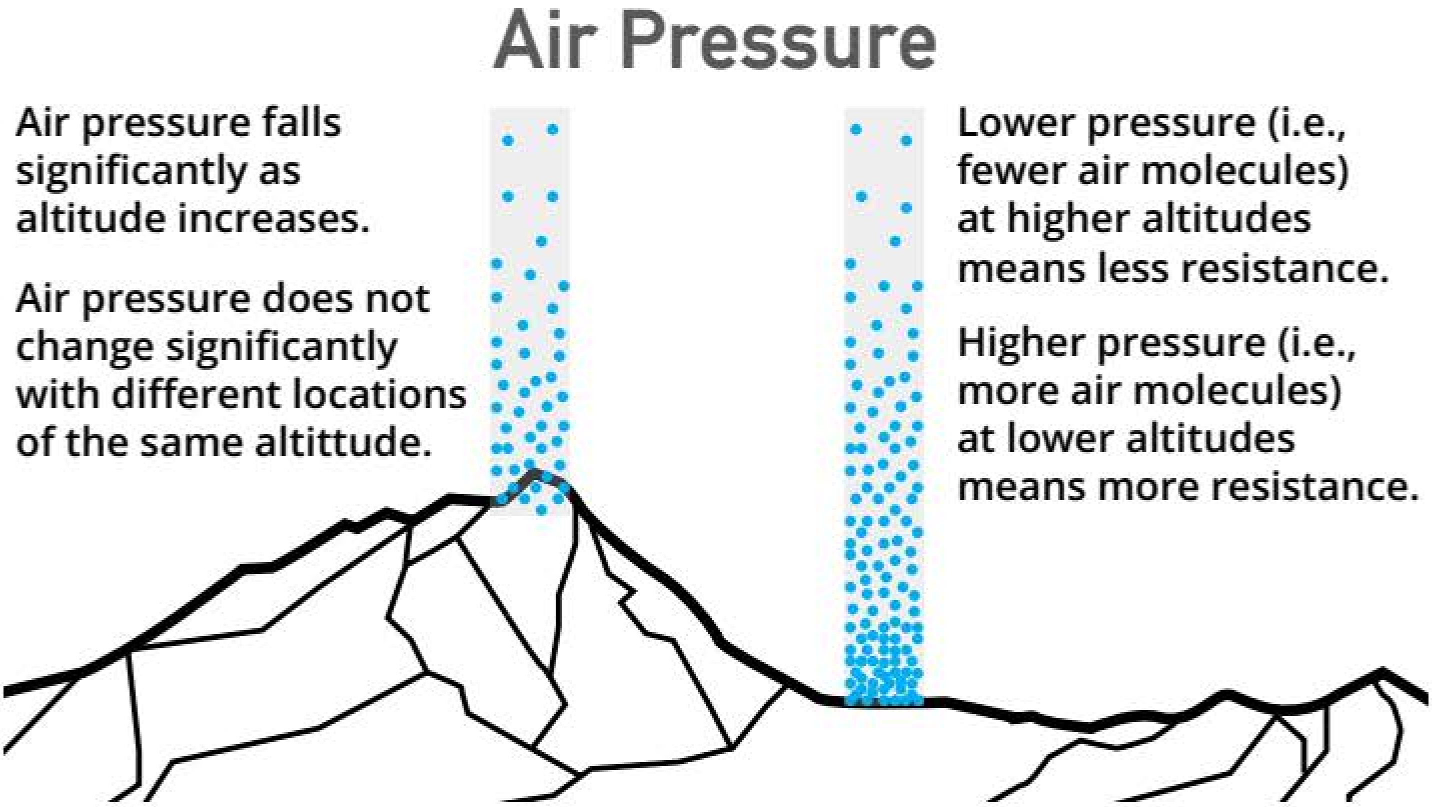

Air Pressure
Air pressure falls significantly as altitude increases.
Air pressure does not change significantly with different locations of the same altititude.
Lower pressure (i.e., fewer air molecules) at higher altitudes means less resistance.
Higher pressure (i.e., more air molecules) at lower altitudes means more resistance.

Image 163: Altitude is the strongest determining factor of air pressure. At the altitudes almost all bullets are fired from, for every 1 km (0.6 mi) of elevation gained, pressure drops by approximately 10%.

windage and elevation holds. However, nowadays, marksmen can read this information from the internet, and then input it into a ballistic calculator and easily obtain the ballistic output. (See Ballistic Calculators, Pg. 221.) If weather predictions are reliable, marksmen can even use forecasts to precalculate air density at different times of day. However, because factors influencing air density change throughout the day, marksmen get the most accurate results by periodically reentering climate data into their calculators.

For whatever reason, a marksman may not want to use the internet, and instead prefer to get analog readings for air pressure, temperature, and humidity respectively from a barometer, a thermometer, and a hygrometer. However, they would still need to input the data into a ballistic calculator, or else perform very arduous trial and error processes as well as calculations to learn how the climate affects their equipment.

When reading the air pressure off the internet, observers must get the station pressure and not the barometric pressure. **Station pressure** is the actual air pressure at a specific location and elevation, reflecting the force exerted by the atmosphere due to the weight of the air column directly above that point.

In contrast, **barometric pressure**, also known as sea-level pressure or adjusted pressure, is the station pressure corrected to a standard reference level, usually sea level. Barometric pressure does not change much based on location. The highest recorded barometric pressure was 108 kilopascals (kPa)

(16 pounds per square inch (psi)) in Siberia, while the lowest was 87 kPa (13 psi) during a typhoon in the Pacific Ocean, representing only about 20% difference in barometric pressure.

Station pressure can change a lot based on location. Not only does barometric pressure influence station pressure, but altitude also affects station pressure. (See Image 163, Pg. 190.) For every 1 km (0.6 mi) of elevation gained, pressure drops by approximately 10 kPa (1.5 psi). (Although the real relationship is curved, this approximated linear relationship holds well enough for everywhere except the high-altitude Andes and Tibetan Plateaus.)

Although not as significant as air pressure, **temperature** also affects air density. As hotter air expands, it becomes less dense at the same pressure if it can expand. However, the reason that temperature does not affect local air pressure as much as it could, is because it cannot freely expand. For air in an area to expand, it must push the rest of the air on earth out of its way in. Regardless, the effect of temperature on air density is just as difficult to determine as the ambient temperature's effect on gunpowder. Marksmen who want extreme accuracy must use quality ballistic calculators.

Finally, air density is also affected by **humidity**, which is the percent of air that is comprised of water in its gaseous form. More broadly speaking, air is a composition of gases, and each gas has a different pressure and density relationship. At the same station pressure, water vapor is less dense than air. Therefore, as the air becomes more humid, it becomes less dense even if the air pressure remains the same. That being said, the effect of humidity is too small for anything but a calculator to consider; going from 0 to 100% humidity may cause a bullet to impact 0.1 mils (0.3 MOA) higher at 1,000 m or yd.

17.c Simple Mirage

Mirage is an optical phenomenon that distorts air and causes objects to appear distorted by wavy or often described as "dancing" or "vibrating" lines. It was briefly explained as it related to wind (See Mirage, Pg. 184.), but mirage is also relevant to shooting in other ways. To explain the concept of mirage again, it occurs when different parts of the atmosphere have varying temperatures and, therefore, different densities. The way light travels through the air is dependent on its density, so alternating pockets of hot and cold air with different refractive indexes result in the wavy vertical lines as hot air rises between columns of denser, colder air (the scientific name is "Snell's law").

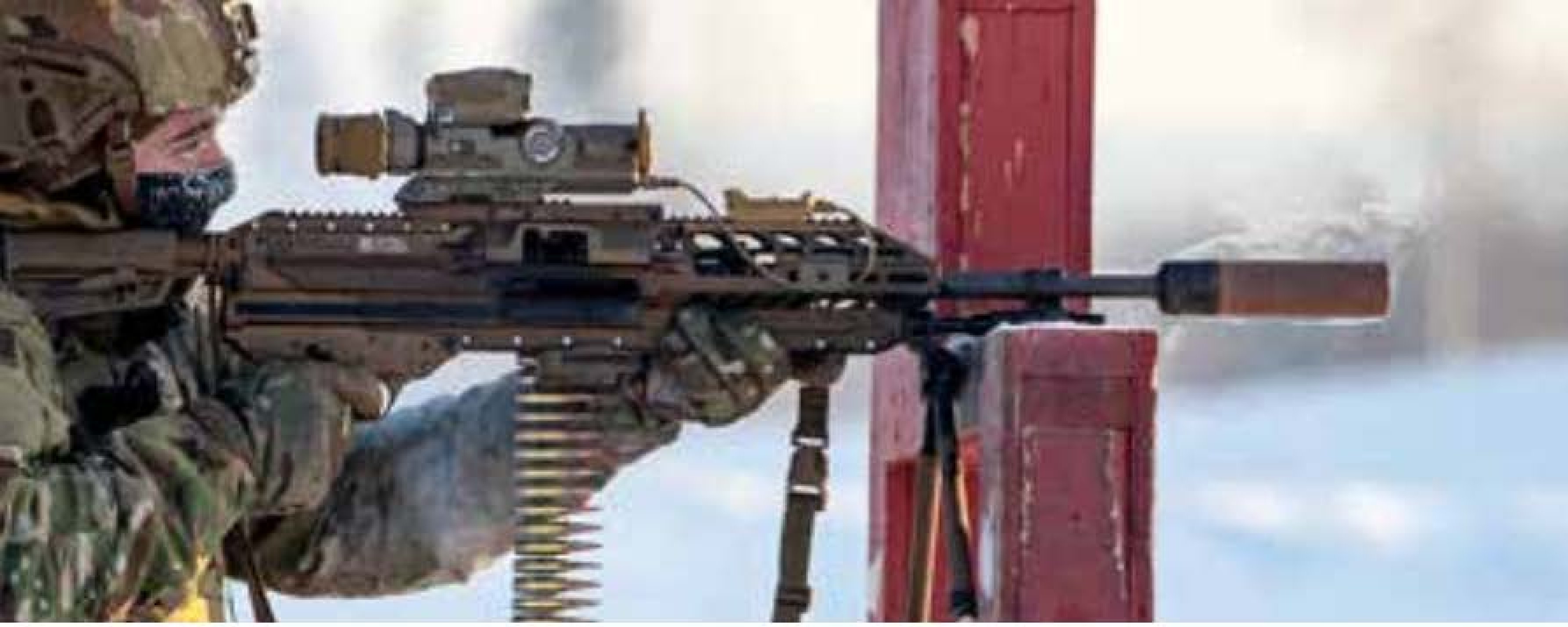


Image 164: A Soldier testing an XM250. This machine gun is fed by a belt of ammunition, so it can fire hundreds of rounds per minute. Such rapid firing creates **mirage on the barrel** (seen here above the suppressor), which can distort a marksman's sight picture through the scope. U.S. Army Cold Regions Test Center, Delta Junction, AK, 20 Feb 2024.

In the context of shooting and using a scope, **mirage can make the target appear distorted or blurry**, making it challenging for the marksman to interpret the scene and thereby aim accurately. To determine the actual location of an object obscured by mirage, it is best to select a specific part of the target. As the image dances in the moving air, there are moments when the mirage momentarily disappears, causing the entire target to snap back into a relatively clear image. By focusing on the chosen section, the marksman can gauge the severity of the mirage shift by observing how much their selected target section snaps back. Because the shift is relatively small, marksmen usually measure the snapback by using their reticle.

Additionally, better optics with lenses that contain fewer defects or better technology may provide a clearer view of both the target and the mirage, making it easier for the marksman to interpret what they see. However, because mirage is a physical property of the air, no lens can completely eliminate it. Lower-end scopes may appear to have more mirage simply because their initial clarity is lower than that of higher-end scopes.

With that said, a common technique for interpreting mirage through a scope is to reduce the aperture of the objective lens. (See Image 165, Pg. 193.) This can be done with a specialized, cheap plastic cap that has a hole in the middle, or simply putting opaque tape over the sides of the objective bell. The size of the aperture directly affects the depth-of-field. (See Image 41, Pg. 62.) With a deeper depth-of-field, the image sharpness for the marksman is enhanced over a greater distance.

Reduced Aperture

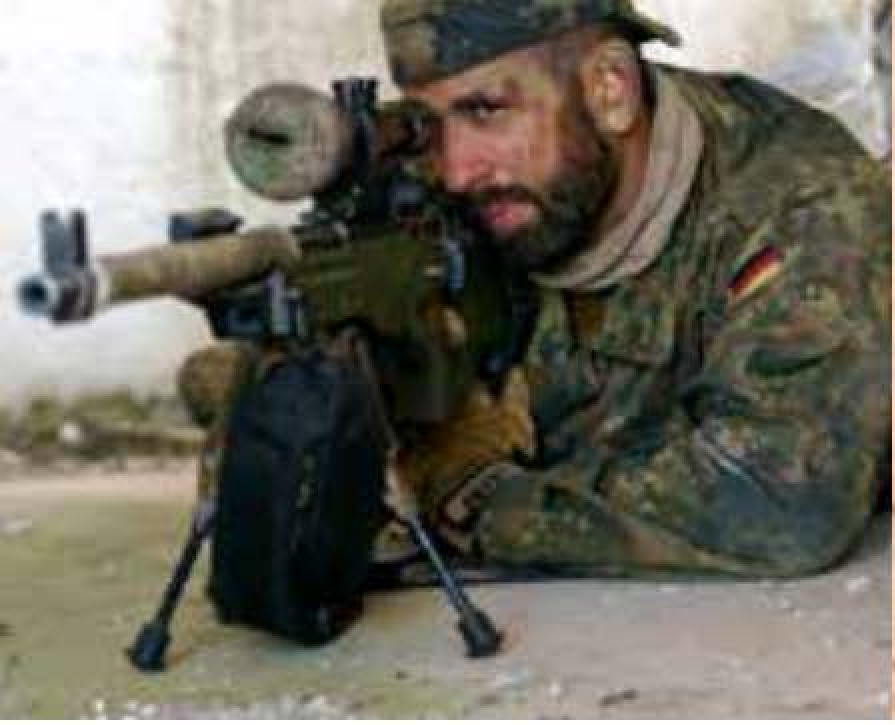


Image 165: A German Army sniper with Jager Battalion 292, looks through his scope. Rukla, Lithuania, 11 June 2015. He has partially covered his objective bell. Covering the aperture increases depth-of-field.

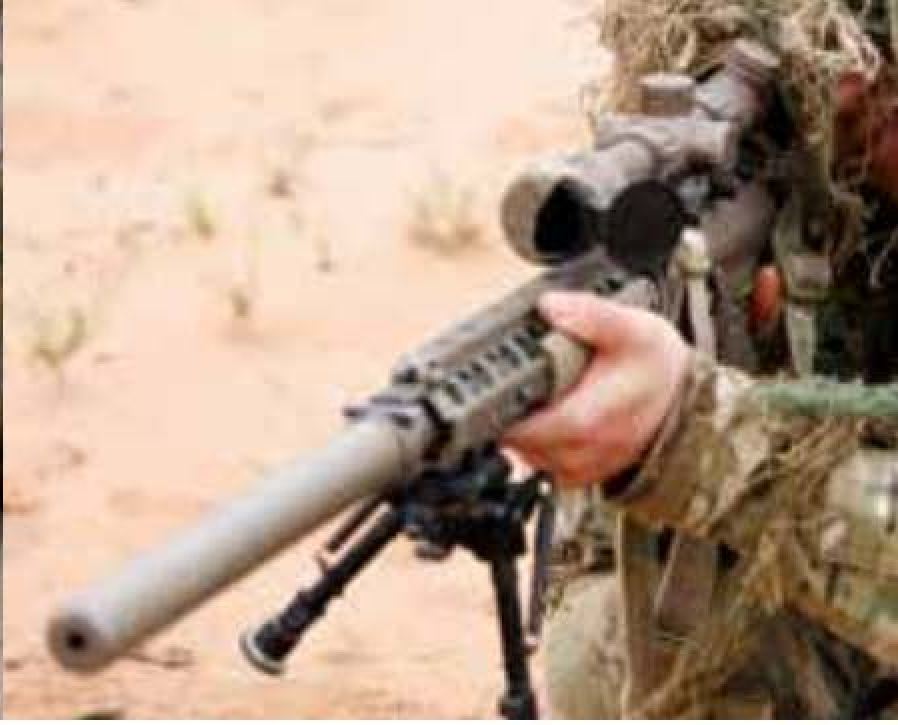


Image 166: An infantryman assigned to the 1st Armored Division uses his M110 semi-automatic sniper system. Fort Bliss, TX, 13 Aug 2019. Covering the aperture prevents the lens from reflecting light (i.e., "glint").

However, one limitation of this technique is that the human eye already limits the objective lens's aperture. In daylight, the human eye's pupil is only about 2 mm in diameter. Reducing the objective lens aperture of a scope won't affect the depth-of-field until the exit pupil of the scope becomes smaller than 2 mm. (See Image 28, Pg. 49.) Another limitation is that when the exit pupil is smaller than the human pupil, the image is less bright to the eye.

A second technique is to reduce the scope's magnification. Again, the effectiveness varies among marksmen and nullifies the effect of reducing the aperture. But the point of this technique is to reduce the relative size of mirage shift to allow the brain to more easily see and interpret the scene as a whole.

An expert marksman knows, however, that the most effective way to mitigate mirage is to **avoid it entirely**. For example, a marksman can avoid direct midday sunlight or mornings when dew cools the ground, both of which are events that commonly create mirage. Alternatively if waiting is not an option, a marksman can look to the sky for moving clouds and wait for one to provide shade, as this can significantly reduce any effects of mirage.

Mirage is not only induced by the sun hitting the ground, but also by the rifle itself. A heated barrel can create a large enough temperature differential with surrounding air that mirage appears to float away from it. (See Image 164, Pg. 192.) Although this mirage is very limited in area, it occurs directly in front of the scope, obscuring a marksman's entire sight picture. In fact, this problem is so common that it has its own name: "scope mirage."

To fix scope mirage, marksmen can cover the hot barrel or suppressor. There is specialized equipment available to purchase; however, the traditional fix is to put a piece of cardboard, such as a used ammo box, over the hot suppressor. Ignition of the cardboard is rarely a concern because scope mirage is a clear indicator to a marksman that their barrel is getting too hot, and that they must slow down their rate-of-fire to make the mirage go away.

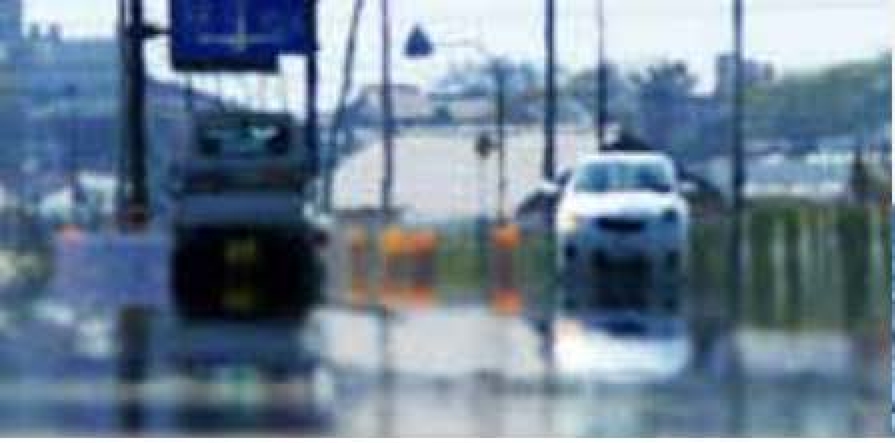
17.d Inferior and Superior Mirage

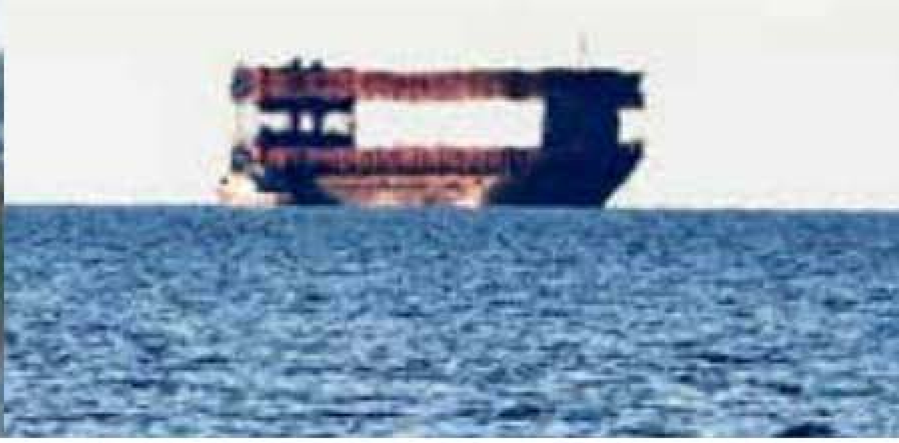
Apart from dancing air, mirage may also cause macro effects that shift an entire section of the marksman's sight picture. Generally, these macro mirage-shifts distort the image of an object towards the hotter air. If there is wind present, the mirage may even shift the image sideways towards hotter air.

An "**inferior mirage**" occurs when hot air is closer to the ground and displaces the image of a distant object downwards. This type of mirage is commonly observed in places where the ground is significantly warmer than the air above it, such as roads or deserts. (See Image 167, Pg. 195.) When shooting at the center of a downwardly distorted image, shots land low on the target object.

In contrast, a "**superior mirage**" is when the image of the object appears above its actual position. This type of mirage typically occurs in colder regions or areas that experience evaporative cooling in the morning, causing the air near the ground (or water) to be cooler than the air above it. As light passes from the cooler air into the warmer air, it is refracted downwards, making the object appear higher. (See Image 168, Pg. 195.) When shooting at the center of a higher image, shots land high on the target object.

This information is provided not for the sake of precise calculations, but rather to explain why a rifle that is zeroed in the morning might drift in the afternoon. The equipment itself is not shifting, but **the sight picture is drifting** instead. Applying this information to practical shooting is challenging because predicting mirage is as difficult as predicting slight variations in air temperature throughout the bullet's flight path. However, as a general guideline, marksmen can remember that heavy mirage may cause a vertical displacement of up to a maximum of 0.5 mils (2 MOA) up or down, although almost all vertical displacements are actually much lower than that.





Inferior and Superior Mirage

Image 167: Inferior mirage shows a reflection of the real image below the real image.

Image 168: Superior mirage shows a fake, right-side-up image of the real image above the real image.

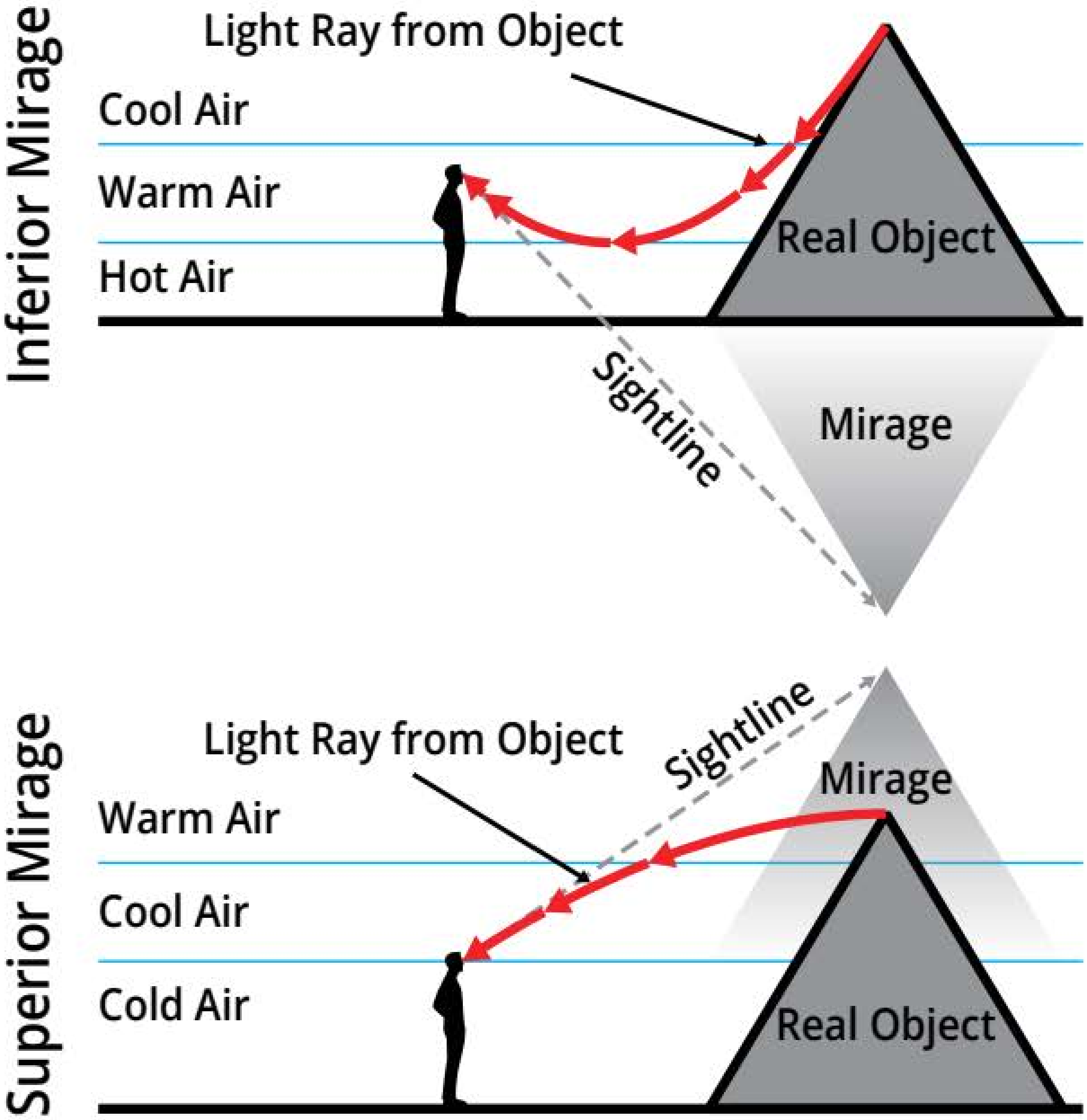

Inferior Mirage
Light Ray from Object
Cool Air
Warm Air
Hot Air
Real Object
Sightline
Mirage
Superior Mirage
Light Ray from Object
Sightline
Mirage
Warm Air
Cool Air
Cold Air
Real Object

Image 169: Differences in air temperature and therefore air density cause light to bend. However, the brain assumes all light travels in a straight line (i.e., the sightline). Therefore, bent-light images, called "mirages," appear to be in a different place than the object actually is. For inferior mirage, the object appears flipped and located below the real object's actual location. For superior mirage, the object appears right-side-up, but above the real object's actual location. The point of these diagrams is not to say that marksmen may mistake the mirages for the real thing, but rather that **mirage is capable of shifting an entire sight picture**.

17.e Precipitation

Unlike air density, precipitation has **minimal impact** on a bullet's trajectory. While water concentrated at the muzzle could cause the bullet to deviate, rain is spread out over a distance, and a few raindrops in a light rainstorm are unlikely to have a significant impact on the bullet's trajectory. In fact, due to the bullet's supersonic air jacket (a layer of air that surrounds the bullet (See Image 113, Pg. 131.)), precipitation may never even come into contact with the bullet's surface in the first place.

To put this into perspective, consider a candidate for the world record for the heaviest rainfall in an hour (i.e., rainfall rate): 36 cm/h (14 in/h). Even in such extreme conditions, this equates to only 0.01 cm/s (0.004 in/s) of water falling, and a normal heavy rain would be less than 1/10 of that.

In sum, **rain feels denser than it actually is**. This can be proven with calculations. Normal terminal velocity of rainfall is 7 m/s, but this example rounds up to 10 m/s for easier calculations. Combining the rainfall rate with the rainfall velocity gives the rainfall density in the air:

(Rainfall Rate) = 36 cm/h = 36 cm ÷ 3,600 s = 1/100 cm/s
(Rain Velocity) = 10 m/s = 1,000 cm/s
(Rain Density) = *(Rainfall Rate)* ÷ *(Rain Velocity)*
(Rain Density) = (1/100 cm/s) ÷ (1000 cm/s)
(Rain Density) = 1 ÷ 100,000 = 0.001%

Separately, the volume of a bullet's trajectory can be determined, which represents the space that a bullet occupies during its flight. The volume can be calculated by multiplying an area *(Bullet Cross-Section)* by a length *(Bullet Trajectory)*. In this case, the cross-section is simplified to 1 cm^2 for ease of calculation, although the cross-section of most bullets is significantly smaller. Also, this example uses a trajectory of 1,000 meters for easier calculations.

(Volume of Trajectory) = *(Bullet Cross-Section)* × *(Length of Trajectory)*
(Bullet Cross-Section) = 1 cm^2
(Length of Trajectory) = 1,000 m = 100,000 cm
(Volume of Trajectory) = 1 cm^2 × 100,000 cm
(Volume of Trajectory) = 100,000 cm^3

Image 170: An Albanian sniper and his spotter prepare for a shot. Zagan Training Area, Poland, 20 May 2016. The sniper **keeps his scope covered** until he is prepared to take a shot, and relies on his spotter to search for targets. This photo is very clear despite intense rainfall, showing that rain is always sparse in the air.

By multiplying the two results, *(Rain Density)* and *(Volume of Trajectory)*, the volume of water in the flight path can be determined.

$$(\textit{Volume of Water}) = (\textit{Rain Density}) \times (\textit{Volume of Trajectory})$$

$$(\textit{Volume of Water}) = (1/100{,}000) \times 100{,}000 \text{ cm}^3$$

$$(\textit{Volume of Water}) = 1 \text{ cm}^3$$

The primary concern in considering precipitation's effect on bullets, is **rain getting inside the barrel**. That is why protecting the muzzle is important. To prevent this, some marksmen also use tape to cover the rifle's barrel, but tape must be reapplied after each shot. The more common (and practical) solution is to shoot under covering. Also, when shooting outdoors in the rain or when rain is expected, it is advisable to bring waterproof clothing and some kind of cover to keep the ammunition dry.

If lightning is expected, it is best to consult with the range officer to determine if it is safe to continue shooting, as lightning strikes have killed many people. Mist and fog are only relevant insofar as they obscure the sight picture and affect humidity. Shooting in limited visibility conditions is always dangerous and not recommended.

18. Inherent Imprecision

Precision refers to how closely multiple shots hit relative to each other. A marksman can increase their precision by, for example, steadying their rifle or using timed breathing correctly. With that said, there are some sources of imprecision that **cannot be eliminated**. For example, one cartridge may have gunpowder positioned slightly differently than in another cartridge, causing exploding gas to push on a bullet differently.

The imprecision that is inherent to the equipment being used can be reduced by switching to different equipment; for example, buying more consistently manufactured ammunition. Another example would be buying bullets with lower air resistance. This is because air, being a moving fluid, has different, constantly changing densities from one cubic meter to the next, and the only way to reduce the influence of air resistance is to use high-quality bullets that experience less aerodynamic forces. (See Image 114, Pg. 131.)

Even then, imprecision cannot be eliminated; all equipment has some amount of inherent imprecision. In other words, part of the deviation of every bullet from the point-of-aim is effectively random. Therefore, accounting for precision is an important part of shooting, and it is the reason why using groups of shots is better than using single shots to zero a weapon. (See Grouping, Pg. 74.) At the expert level, marksmen assign a probability to each shot hitting their target with even perfect technique. This concept of thinking probabilistically instead of in certain terms is called "**probabilistic shooting**."

Probabilistic thinking is often applied to estimates, which are notorious for being imprecise. Laser rangefinders have largely mitigated the imprecision of estimates of a target's distance from a marksman. However, estimation still remains an important part of determining wind speed, even in today's technologically modern shooting era.

18.a Lateral Throwoff

Lateral throwoff refers to a bullet's unpredictable sideways deflection from the marksman's intended trajectory as the bullet exits the firearm. This deflection occurs because the bullet experiences uneven force, either from exploding gas applying uneven force to its rear, or lift applying uneven force to its front.

The phenomenon is a "throwoff" because it is sudden. In the bore, the bullet follows the bore; however, when the bullet leaves the bore, it is suddenly no longer stabilized by the bore's tight fit, and quickly deflects laterally.

Lateral Throwoff

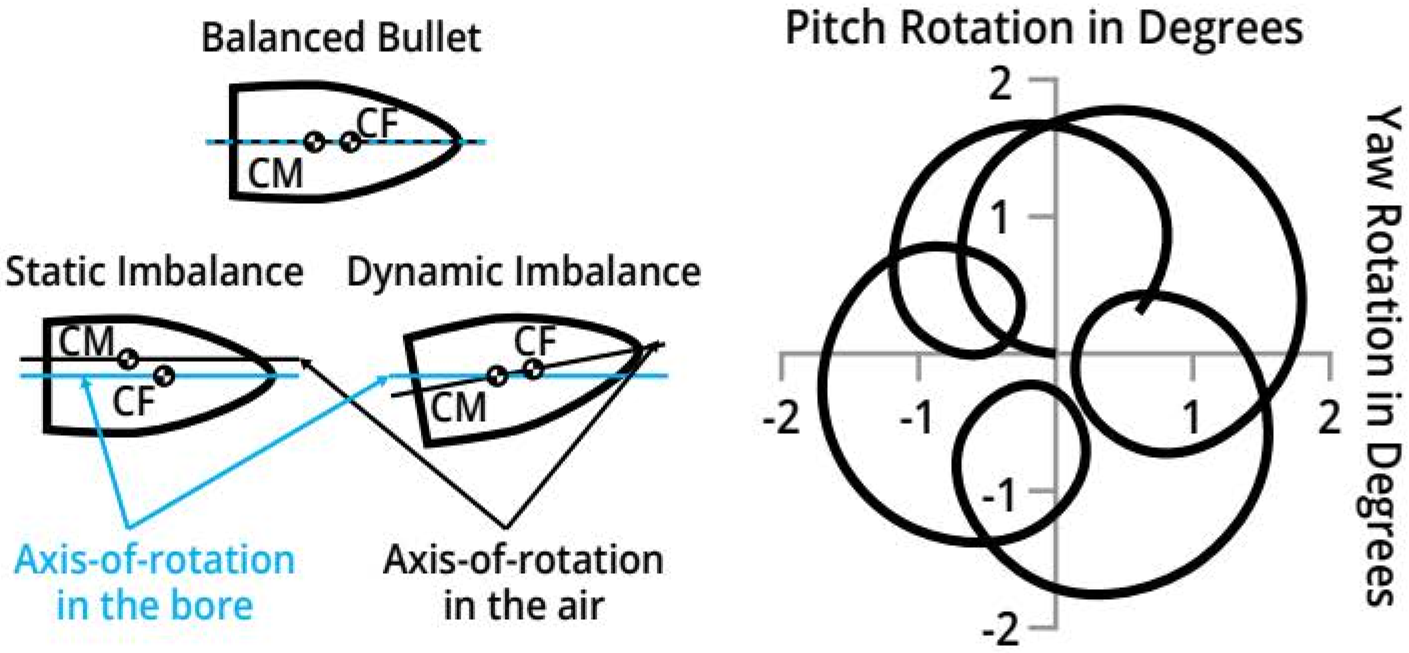


Image 171: A perfectly balanced bullet rotates from the tip to the tail on the same axis in the bore and in the air after it leaves the muzzle. However, **perfect bullets don't exist** and always have some (perhaps imperceivable) static and dynamic imbalance. Static imbalance occurs when the center-of-mass (CM) through the bullet is on a different axis from the center-of-form (CF) through the bullet. This occurs when multi-material bullets do not have their different materials equally rotationally distributed. A statically imbalanced bullet deflects due to inertia as the bullet changes from one axis of rotation to another. Dynamic imbalance occurs when a bullet is slanted in the bore, so that the center-of-form is not aligned with the boreline. A dynamically imbalanced bullet catches air as it exits the muzzle, causing lift force to deflect the bullet. The example graph on the right shows where an example bullet-tip pointed as it left the muzzle for the first 15 yd (13.7 m) due to either static or dynamic instability.

Not all of the sideways deflection is random; however, any consistent deflection is accounted for during the zeroing process. Therefore by definition, lateral throwoff is the change to a bullet's trajectory that is impossible to predict or account for.

Lateral throwoff has multiple causes. The first cause discussed here is the **static imbalance** caused by a difference between a bullet's center-of-form and its center-of-mass. The center-of-form is the point that is the furthest on average from every point on the bullet's surface; and the center-of-form axis is the line drawn through the center-of-form for each two-dimensional cross-section of a bullet. When a bullet spins inside the barrel, it rotates around this center-of-form axis because the shape of the bullet is confined within the bore.

On the other hand, the center-of-mass is the point where the bullet's mass is evenly distributed in all directions. For any circle (e.g., the cross-section of a bullet) made of a single material, the center-of-form is the center-of-mass.

However, in bullets made of multiple materials, such as those with a copper jacket and a lead core, the center-of-mass might not align with the center-of-form. (An easy-to-visualize example of this is a bottle that is halfway-filled with water, laid on its size, and frozen. Then, the remaining half is filled with liquid water. Because ice is less dense than water, the bottle's center-of-mass is within the water, but the center-of-form is in the middle of the bottle.)

If the center-of-mass does not fall on the center-of-form axis, and the bore contains the bullet and forces it to rotate around the center-of-form axis, then that means that the center-of-mass travels through a bore in a helical or spiral path. However, when the bore no longer confines the bullet (i.e., when the bullet exits the muzzle), the bullet is free to spin around its center-of-mass. Therefore, the center-of-form must then travel in a helical path.

When the center-of-mass spins in a helix, it **retains angular momentum** in the direction it is spinning. (See Momentum, Pg. 246.) Therefore, when the center-of-mass is allowed to travel straight, it retains that angular momentum and is slightly diverted into the direction it was spinning in. This diversion is referred to as lateral throwoff.

In fact, this cause of lateral throwoff is the limiting factor on bullet spin. The more a bullet spins, the greater the angular momentum of its center-of-mass, and the greater the lateral throwoff. As such, bullets are not spun as fast as the materials would otherwise allow, as greater rotation would result in increased lateral throwoff. In other words, long-range marksmen prefer to use the slowest possible twist rate that stabilizes a bullet in flight.

As previously mentioned, a likely cause of a misaligned center-of-mass is manufacturing defects in the bullet, resulting in one side of the bullet jacket being thinner than the other side. Since the marksman does not know the orientation of the center-of-mass (cartridges are radially symmetrical and can be loaded into rifles with any rotation about their axis), the final vector of momentum is also unknown, making the lateral throwoff effectively random. In fact, excellent mass balance to reduce lateral throwoff is a major selling point for high-grade ammunition and shorter bullets (consistent jacket thickness is easier to maintain on shorter bullets).

Besides imperfect mass distribution in the construction of a bullet, a second reason for lateral throwoff is the **dynamic instability** caused by a mass misalignment from exiting the bore with a spin axis that is not aligned to the axis of the bullet's rotational symmetry (in simple terms, the bullet tip doesn't point forward). (See Image 171, Pg. 199.)

This can be caused by a bullet entering the bore at an angle instead of straight. An angled entry could in turn be caused by any number of reasons: bullets that are not aligned properly in their case; a chamber or throat that is not concentric with or sized comparatively to the bore; a configuration that leads bullets to catch the rifling and continue down the bore in that slightly angled orientation; etc.

With an angled entry into the bore, the tip of the bullet would rotate spirally, causing the center-of-mass to also misalign with the center of the bore. Equipment with low part tolerances is especially prone to angled bullets. Military and hunting rifles, for example, require some level of clearance between the rifling and the bullet to accommodate the inevitable ingress of dirt and grime into the action and bore of the rifle. On the other hand, while marksmen can buy high-tolerance equipment to reduce lateral throwoff, getting that equipment dirty may greatly impede performance in other ways.

Besides mass imbalance, **uneven gas escape** as the bullet exits the bore is another cause of lateral throwoff. If gas escapes from one side of the bore faster than from the other side, the bullet experiences uneven pressure and therefore undergoes a slight turn away from the stronger-pushing gas. This is due to a few reasons. First, gas is a fluid and as such is not always predictable. Second, uneven lateral gas escape can physically push the rifle sideways, causing unpredictable secondary effects. Finally, escaping gas can exacerbate the aforementioned mass-imbalance effects.

Uneven gas escape can, in theory, be caused by the crown (i.e., the final part of the bore to touch the bullet) not being concentric around the bullet. The concentricity of the crown is the variation in the distance between the crown and the tail of a bullet as it exits the rifle (ideally both are perfect circles, but in practice both have microscopic or macroscopic defects). However, in practice, groupings made with rifles with heavily damaged crowns are indistinguishable from those made with fresh crowns at 100 m or yd. It is actually the boreline alone that shifts. That is, error is introduced, but it is the same error for every shot and is therefore predictable and accounted for with a new zero. A crown that is damaged in the middle of a shooting session may only appear to lose precision as the boreline shifts from one location to another, causing marksmen to not trust their original zero.

18.b Probabilistic Shooting (Mil and MOA-Accuracy)

When bullets are fired, they invariably encounter random forces that cause their trajectory to deviate from the marksman's point-of-aim. The resulting imprecision is not just difficult to avoid, but it is impossible to avoid. Therefore, expert marksmen must learn to account for imprecision caused by random forces, and hit their targets anyway.

The first step is to reframe shooting as the act of firing groups instead of single shots. (See Grouping, Pg. 74.) This is because, whereas a single bullet may follow a relatively linear trajectory, a group of bullets, when fired together, forms a pattern of dispersion that widens as they travel farther from the muzzle. This pattern is referred to as a "**conical trajectory**" or "**cone-of-fire"** meaning it resembles the shape of a cone for which the point is at the muzzle and the base spreads out as distance increases. (See Image 172, Pg. 203.)

When the bullets in the cone-of-fire meet the target, they randomly impact around a central point (i.e., the point-of-aim for an accurate marksman). The bullet impacts create an elliptical, or circle pattern, with more bullets at the center of the ellipse and fewer around the edges. (See Image 173, Pg. 203.) This pattern in statistics is known as a "bivariate normal distribution." The definitions of each term are:

Bivariate – refers to involving two variables; in this case, the horizontal and vertical distances from the point-of-aim in the center.

Mean – is the average value of a set of data points; in this case, the mean is the center of the impacts (i.e., the point-of-aim for an accurate marksman).

Dispersion – is how a set of points is distributed or spread over a wide area. In shooting, high dispersion is low precision, and vice versa. Higher dispersion means a larger ellipse.

Standard deviation – measures the dispersion of data points around the mean. A smaller standard deviation means the impacts are clustered around the mean, showing higher precision. A larger standard deviation indicates that the impacts are more spread out, showing lower precision.

Normal distribution – describes how data points (here, bullet impacts) are distributed for a given mean and standard deviation so that most are near the center (i.e., the mean), and fewer are farther away.

The goal of probabilistic shooting is to ensure that the normal distribution of a marksman's grouping fits within their target area well enough, allowing only

Cone-of-Fire

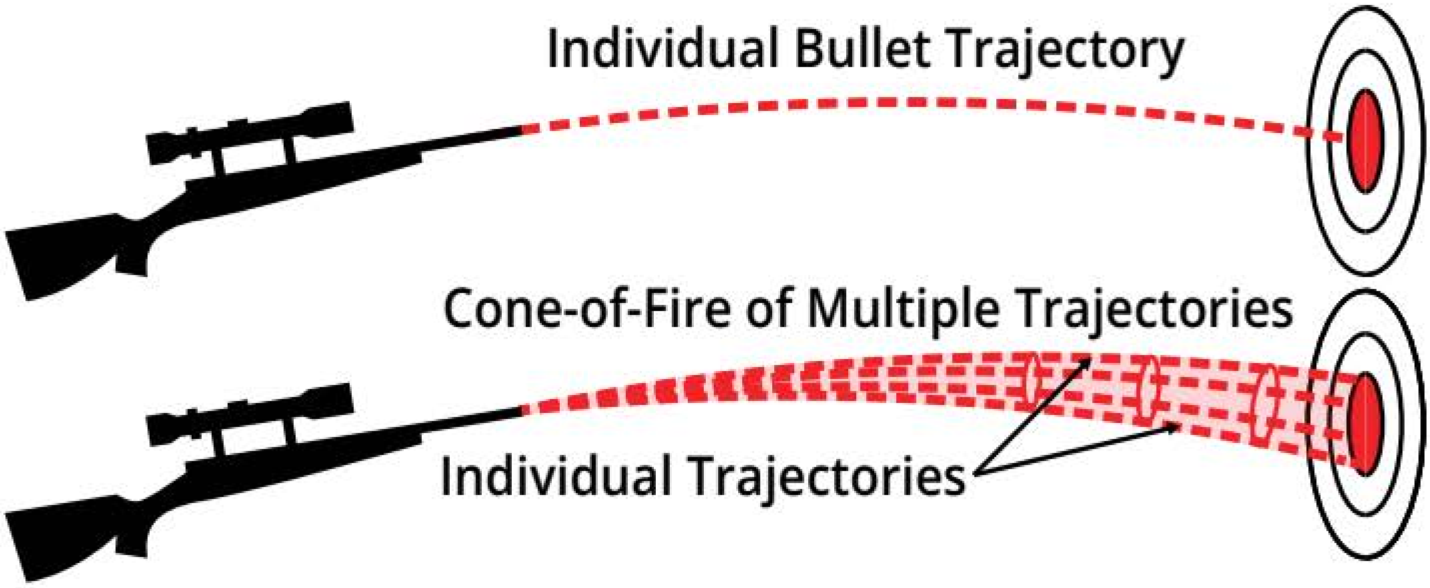

Individual Bullet Trajectory
Cone-of-Fire of Multiple Trajectories
Individual Trajectories

Image 172: Every bullet fired from a rifle has its own trajectory. However, they all originate from the rifle's muzzle. Therefore, all the trajectories fit within a (bent) cone shape called the "cone-of-fire." A major goal of marksmen is to make the cone **as narrow as possible**.

Normal Distributions of Shot Dispersion

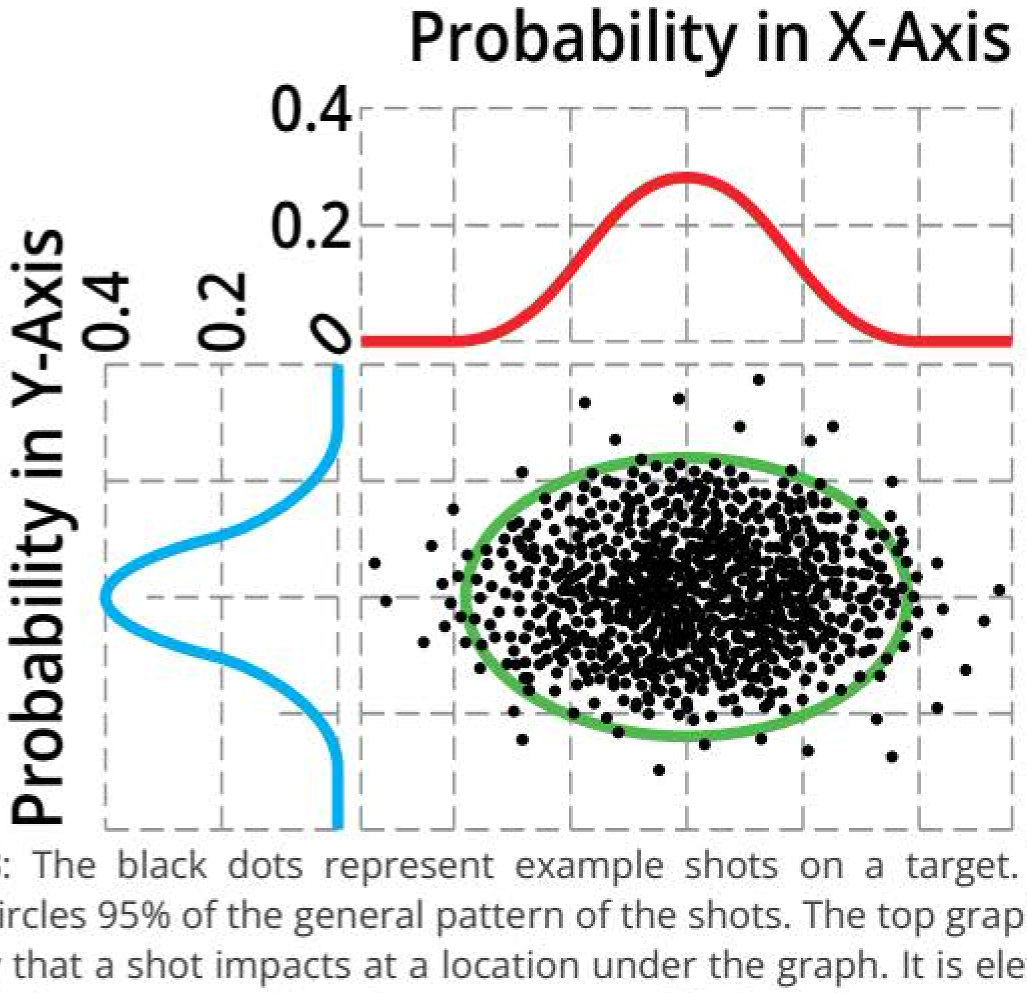


Image 173: The black dots represent example shots on a target. The center ellipse encircles 95% of the general pattern of the shots. The top graph shows the probability that a shot impacts at a location under the graph. It is elevated in the center, which represents that **shots are more likely to impact at the center** of the X-axis. Similarly, the left graph shows that shots are more likely to impact at the center of the Y-axis than on the edges. The top graph is a different shape (wider) than the left graph (narrower) because most effects work independently to affect either windage (e.g., wind) or elevation (e.g., estimating range), but not both. Both the top and left curves are called "**normal distributions**," and entire disciplines of statistics are dedicated to them.

an acceptable number of bullets to miss. While it's theoretically impossible to achieve an error rate of 0%, it can be reduced to extremely low levels, such as 0.0001% of shots missing the target.

To decrease their error rate, marksmen can either reduce standard deviation or enlarge the target area. Standard deviation can be decreased and precision increased through methods such as more practice and better equipment. The target area can be made bigger by bringing it closer.

For example, big-game hunters often target the heart of an animal because hitting it instantly secures the kill. Assuming that the heart is a circle with a radius of 10 cm (3.9 in), using traditional thinking, bullets follow the marksman's point-of-aim in a straight line to be able to hit the deer's heart 100% of the time regardless of distance. However, in reality, dispersion means that bullets do not follow a single, predicted trajectory; and to hit the deer's heart 100% of the time, the deer must be close enough to the marksman so that the marksman's cone-of-fire overlays the target area.

There are instances where a marksman may struggle to narrow their cone-of-fire enough to reduce their impact area to a size smaller than the target area. In such cases, some bullets hit the target while others miss. **Shooting multiple times to ensure that at least one bullet hits the target is a viable strategy**. Machine gunners are more familiar with this concept, as their weapon systems are designed to compensate for extreme dispersion with an extreme rate-of-fire.

However, before a marksman can effectively work with their rifle's dispersion pattern, they first need to identify what that pattern is. In practice, this can be done during the process of zeroing and grouping (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.) Each group of shots on the target represents the marksman's best effort to be precise under ideal conditions, making it a good indicator of the bullets' minimum dispersion. By measuring the angular distance between the bullet holes in a group (i.e., the diameter (See Grouping, Pg. 74.)) the marksman can obtain a simplified measure of the diameter of their cone-of-fire (e.g., 0.5 mil or 2 MOA). (The measure is simplified because a normal distribution only has a diameter that corresponds to a percent, so for example 99% of bullets may be within 0.5 mils.) However, getting the diameter for a few groupings is very useful because a marksman can determine whether that diameter fits within the area of their target.

This diameter of a rifle's cone-of-fire is often advertised by rifle sellers and manufacturers. They advertise with terms such as "mil-accurate" or "MOA-accurate" which refer to the precision or dispersion of the cone-of-fire. For

Mil-Accuracy and MOA-Accuracy

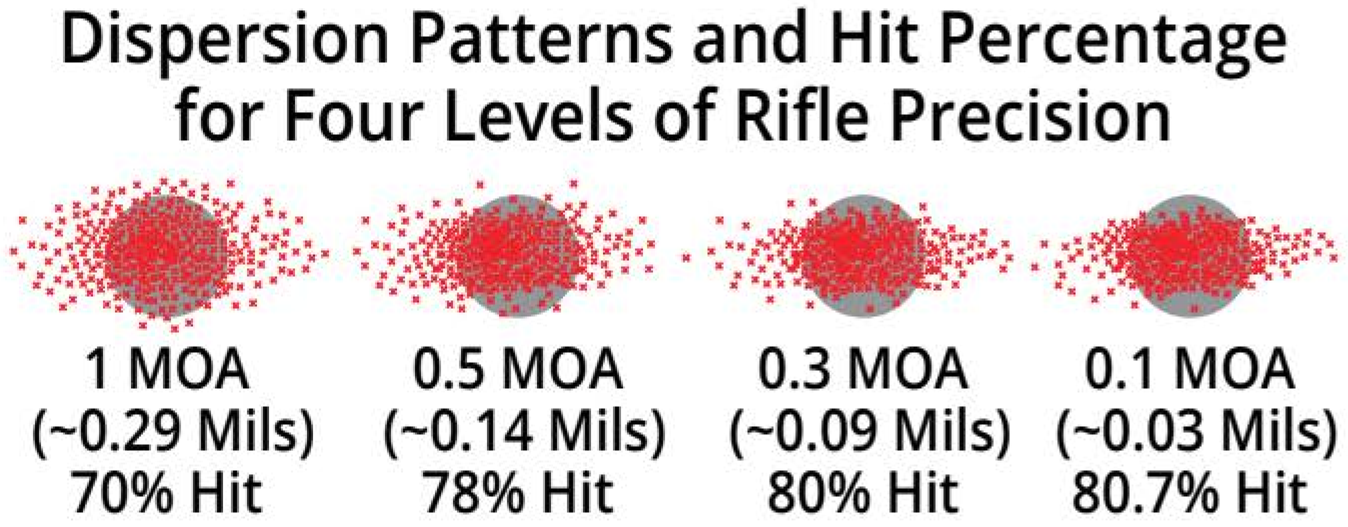

Dispersion Patterns and Hit Percentage for Four Levels of Rifle Precision
1 MOA
(~0.29 Mils)
70% Hit
0.5 MOA
(~0.14 Mils)
78% Hit
0.3 MOA
(~0.09 Mils)
80% Hit
0.1 MOA
(~0.03 Mils)
80.7% Hit

Image 174: These shot patterns represent four rifles with different precisions. The hit percentage is the number of shots that landed on the gray, circular target. Even though the 1 MOA rifle is 10 times as precise as the 0.1 MOA rifle, the former was only ~10% more precise on the target. This is because of other sources of inherent imprecision. For example, these dispersion patterns included the same wind uncertainty, which is why all of the widths are roughly the same. The point is that often, **equipment is not the largest source of inherent imprecision**.

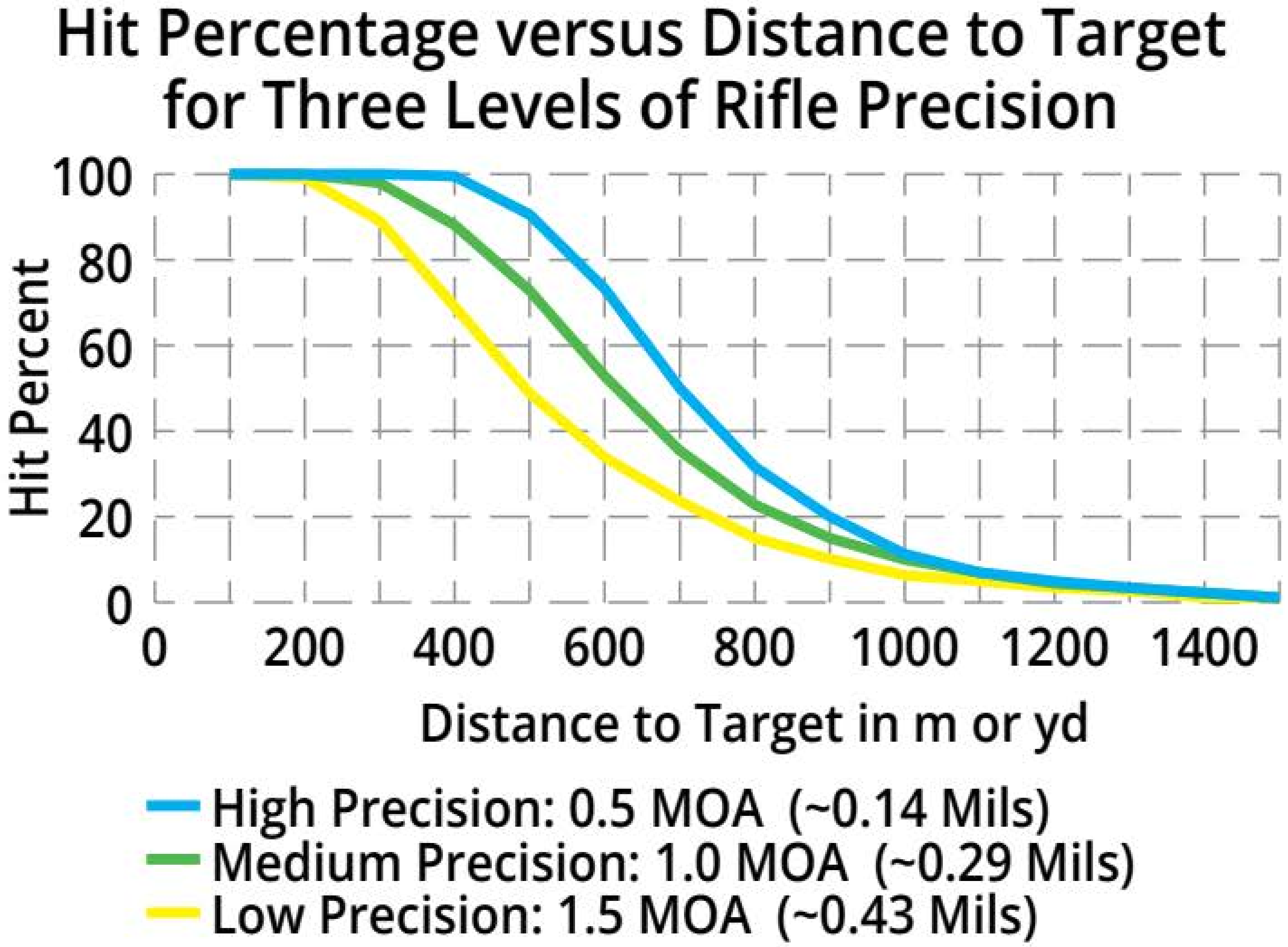


Image 175: This graph reinforces the diagram above: at longer ranges and outdoors, modern equipment is usually not the largest source of imprecision. Even at the largest vertical difference, doubling the rifle precision did not double the hit percentage. This is because other factors, such as wind estimates, distance uncertainty, and inconsistent gunpowder power all cause imprecision as well.

example, if a firearm is fired from a vice and the impact area has a dispersion of 0.3 mils, then the rifle is considered a “0.3 mil-accurate” rifle. As explained previously, using a number to describe width without stating what percent of shots that width encompasses is problematic. However, comparing a single-number mil-accuracy or MOA-accuracy between two rifles is far easier than comparing their normal distributions.

Different shooting disciplines have different standards on what error rates or dispersion patterns are acceptable. For example, benchrest marksmen, compared to hunters, have much smaller target areas at the same distance. Therefore, they are much more stringent about reducing potential sources of dispersion. To be as precise as possible, they shoot from rigid setups.

The general task of reducing dispersion starts with identifying the various sources of imprecision. Of course, **the greatest source of imprecision is the marksman** themself, which is why benchrest marksmen place their rifles in vices and other similar devices to remove human interference. Similarly, good marksmen practice a lot to reduce their error rate as much as possible.

However, reducing error from external factors is more complicated, and often depends on the distance one is shooting at. At close ranges, equipment becomes a significant source of dispersion. On the other hand, wind exerts a continuous, albeit small, effect on a bullet, becoming a more significant source of dispersion over longer trajectories.

Using a DOPE book, marksmen can effectively record and analyze information from each shooting session to identify the factors causing variation in their dispersion. Data points recorded for a given distance might include: the mil-accuracy of their rifle; the standard deviation of muzzle velocity of their ammunition; and weather data on wind speed variability and the likelihood of gusts. This recording process requires a significant amount of shooting, as each new variable introduced in multivariate testing requires collecting an increased number of data samples.

After all the data is collected, it can be input into statistical computer programs for analysis. However, even with a computer, statistical identification of the source of standard deviation (i.e., the source of imprecision) can be a complicated and challenging subject. This complex subject is best explored in and left to a comprehensive book on statistics.

18.c Estimation (Range and Wind) Uncertainty

Modern equipment has severely improved the precision of the data with which marksmen determine their trajectories. Laser rangefinders give exact distances to the target within less than 0.1% accuracy up to 1000 m or yd, and electronic wind meters also give extremely precise wind information (albeit only regarding the wind next to the meter).

Therefore, it is worth explaining how more precise inputs lead to much more precise bullet trajectories. This explanation not only shows the limitations of human estimates, but also shows why even novice marksmen can improve their precision by using specialized equipment.

Range uncertainty (expressed as a percentage) is the accuracy of an estimate of the distance from a marksman to their target. For example, a high-quality laser rangefinder can boast an accuracy of less than 0.1% error over distances up to 1000 m or yd, or 0.1%. In contrast, a marksman is considered a good estimator if their guess is within 10% of the actual distance.

Range uncertainty affects vertical placement (bullet-drop) on the target, and the elevation hold that marksmen use to compensate for that drop. Therefore, to ensure a hit despite an inaccurate range estimate, the elevation hold must compensate for any bullet-drop that would occur within the range of inaccuracy. For example, if a marksman estimates with 10% accuracy, and they estimate a range of 500 m or yd, they must use an elevation hold that would compensate for a bullet both at 450 m or yd and at 550 m or yd (i.e., 500 m or yd minus and plus 10%). (See Image 107, Pg. 124.)

The problem of range uncertainty is associated with its traditional solution, danger distance. (See Danger Distance, Pg. 143.) To restate that section, a bullet always hits a target of a given height within the corresponding distance because the bullet never exceeds the bounds of that height along that distance. That property can be reversed, so that if the height is known, a marksman can determine the danger distance, which is the allowable ranging error.

A much larger problem for marksmen is **wind uncertainty** because wind changes in real time and there exists no portable device that can give accurate wind readings from a distance. (Distance to target can change too, but aside from vehicles, it is extremely rare for a target to be traveling fast enough to cause range uncertainty).

Accounting for wind uncertainty uses a similar concept to danger distance. First, a marksman determines the angular width of their target using the hashmarks on their reticle. For example, assuming a target is 1 m or yd wide at 500 m or yd from the marksman, the target is 2 mils (6.9 MOA) wide. Therefore, if the marksman aims in the center, they can be 1 mil (3.4 MOA) to the left or the right and still hit the target.

To convert that 1 mil leeway into how accurate a wind estimate must be, the marksman can use the wind-to-wind-hold-conversion in reverse. (See Converting a Wind to a Windage Hold (Summary), Pg. 177.) For example, a wind hold of 1 mil at 500 m or yd may correspond to an equivalent crosswind of 15 km/h (10 mi/h). (See Image 140, Pg. 161.) Assume that the wind value is 100% because the wind direction is 90°to the marksman. Therefore in this case, the marksman's estimate of wind speed would have to be plus or minus 15 km/h (10 mi/h) of the true wind speed to still hit the target.

However, obviously narrower targets at farther distances require much more accuracy. A 1/2 m or yd target (half the width) at 1000 m or yd (double the distance) would require an estimate more than 4 times as accurate because **target-width scales linearly** with allowable wind estimation error; but **distance-to-target scales exponentially**.

19. Shooting Uphill or Downhill (Inclination)

Shooting uphill or downhill is common in hilly or mountainous areas. Changes in elevation affect how gravity affects the bullet's trajectory and how the marksman must adjust their point-of-aim vertically, but it does not change the effect of wind or how the marksman must adjust their point-of-aim horizontally.

To understand the effects of shooting uphill or downhill, marksmen must be aware of altitude-related climate effects, but also the "inclination." **Inclination is the angle** between any straight line and an X-axis. For shooting purposes, the straight line is the sightline from the marksman to the target, and the X-axis always lies on the **imaginary plane that is perpendicular to the direction of gravity**. With the inclination, a marksman determines the inclined elevation hold.

(Unrelated to the rest of the section, it is important to note that keeping a good posture during angled shooting is important. Specifically, marksmen who aim up must ensure that they do not rotate their scope towards their eye so much that recoil would force their scope backwards into their eye.)

Inclined Shooting

Image 176: A Finnish Soldier participates in the Advanced High Angle Sniper Course. Lizum, Austria, 27 Apr 2015. Most inclined shots are between a cliff and flat ground, meaning **sightlines are usually less steep than a hillside's incline**.

Image 177: The Mildot Master is an **analog calculator** that calculates bullet-drop for a given distance in both the imperial and metric systems. It can also give a correct elevation hold for any inclination. This makes it useful for milling with a reticle.

19.a Perpendicular and Parallel Components of Gravity

When the bullet flies horizontally, 100% of gravity pulls the bullet away from its trajectory. And if a bullet is shot straight up in the air, 0% of gravity affects the trajectory, as the bullet just flies directly up and down (in a vacuum). Between horizontally and vertically, when a bullet travels at an inclination, somewhere between 100% and 0% of **gravity acts perpendicular to the bullet's trajectory**.

Converting gravity into its perpendicular components requires the use of trigonometry, specifically taking the cosine (cos) of the inclination. (See Image 178, Pg. 210.) This equation can be computed precisely, although it is usually approximated:

- cos(0° to 15°) ≈ 1.0 = 100% of gravity is perpendicular
- cos(15° to 30°) ≈ 0.9 = 90% of gravity is perpendicular
- cos(30° to 40°) ≈ 0.8 = 80% of gravity is perpendicular
- cos(45°) ≈ 0.7 = 70% of gravity is perpendicular
- cos(90°) = 0 = 0% of gravity is perpendicular

Applying gravity percentages to bullets is complex, so marksmen use a method known as the "Rifleman's Rule." This rule simplifies the calculation by considering only the distance that a bullet travels horizontally (i.e., perpendicular to gravity) when calculating an elevation hold, ignoring any changes in altitude. (See Image 180, Pg. 211.)

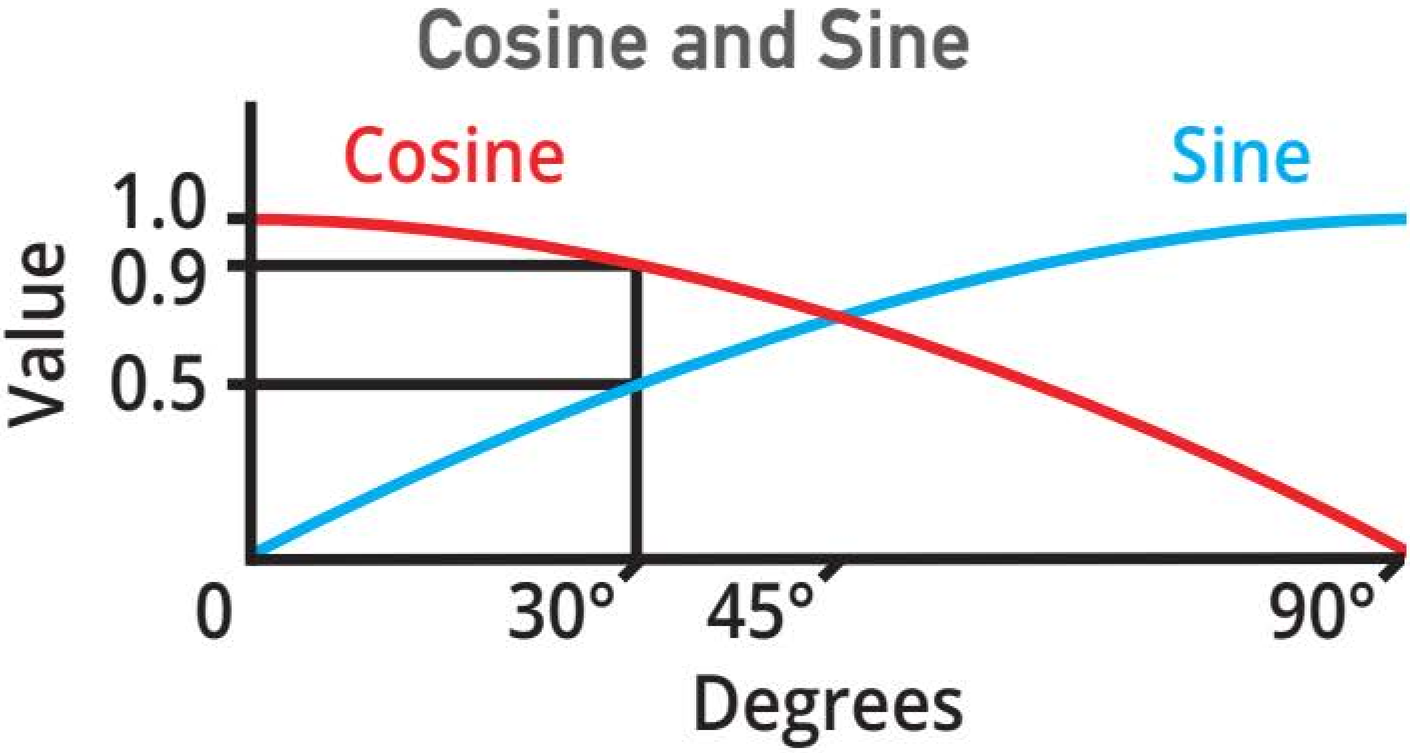


Image 178: In this graph, the X-axis represents the inclination angle, which is the angle between the marksman's line of sight and a horizontal plane (perpendicular to gravity). The Y-axis represents the component value, which is used to calculate how much of the gravitational force acts perpendicular (shown by the red cosine curve) or parallel (shown by the blue sine curve) to the bullet's trajectory at each inclination angle. The two lines are reflections of each other at the 45° mark. This graph includes a vertical line at the 30° mark to show that **cosine changes very slowly at first**. A horizontal line segment is also drawn from the value 0.5 to demonstrate that the component values of sine and cosine sum to more than 1.

For example, if a bullet is fired at a 45° angle toward a target 400 meters (438 yards) away, the rule calculates the horizontal distance that the bullet travels by using the cosine of the inclination. The cosine of 45° is about 0.7, so multiplying this by the total distance (400 meters) gives 280 meters (306 yards) of horizontal travel. Therefore, to compensate for bullet-drop, the marksman can use an elevation hold for a shot at 280 meters on flat ground, even though the actual shot is at a 45° angle over 400 meters.

For angles less than 15° and distances less than 200 m (219 yd), changes in the horizontal distance traveled, and therefore bullet-drop, may be insignificant. (E.g., bullet-drop at 15° is 97% of bullet-drop at 0°.) Although 15° may seem small, marksmen often overestimate elevation changes. For reference, the maximum allowable incline for U.S. Highways is less than 4°, and the steepest roads in the world are less than 18°.

In contrast to the perpendicular component of gravity affecting trajectory, the **component of gravity that is parallel to a bullet's trajectory** affects the bullet's speed. When a bullet flies horizontally, 0% of gravity affects the speed of the bullet; and when a bullet flies vertically, 100% of gravity affects the speed of a bullet. Between horizontally and vertically, when a bullet

Shooting Uphill and Downhill

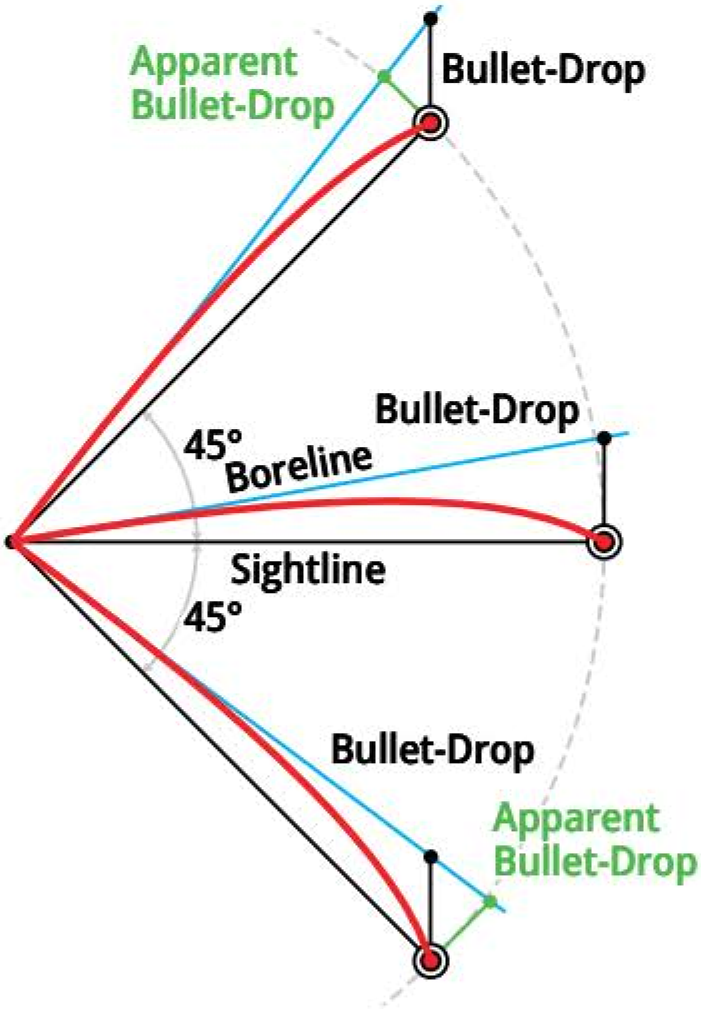

Apparent Bullet-Drop
Bullet-Drop
Bullet-Drop
45°
Boreline
Sightline
45°
Bullet-Drop
Apparent Bullet-Drop

Image 179: **The trajectories of bullets shot uphill or downhill are flatter** than the trajectory of a bullet fired horizontally. This is because gravity becomes more aligned with the boreline. Actual bullet-drop remains relatively consistent regardless of the angle of shooting. However, marksmen **perceive that bullet-drop decreases** because they observe bullet-drop to always be perpendicular to the sightline.

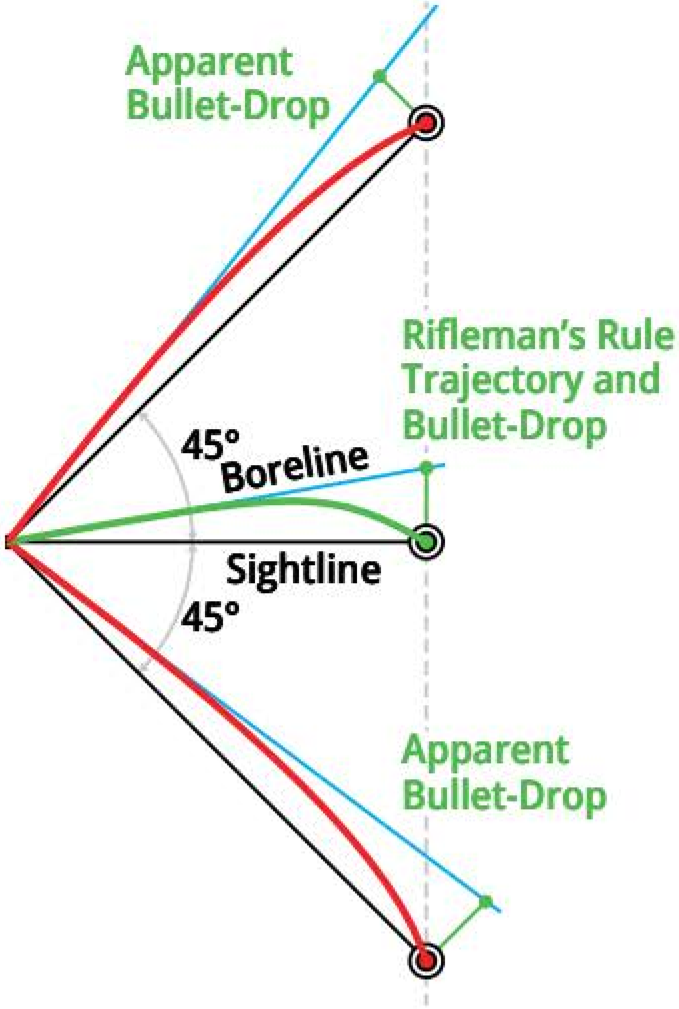

Apparent Bullet-Drop
Rifleman's Rule Trajectory and Bullet-Drop
45°
Boreline
Sightline
45°
Apparent Bullet-Drop

Image 180: To account for the flatter inclined trajectories, marksmen use the **Rifleman's Rule**, which states that the apparent bullet-drop is about the same as the actual bullet-drop of a bullet fired at a target that is the same horizontal distance on flat terrain. (Note, the top and bottom apparent bullet-drops would be much closer in size if the angles between the borelines and sightlines were more realistic (i.e., much smaller).)

travels at an inclination, somewhere between 0% and 100% of gravity acts parallel to the trajectory of the bullet.

The parallel component of gravity is rarely considered. This is because gravity only accelerates or decelerates the velocity of the bullet a small fraction up or down. For example, an average high-powered rifle may have muzzle velocities of 1000 m/s (3281 ft/s). Even if air resistance slows a bullet down to an average velocity of 500 m/s (1640 ft/s), it would take at most 2 s to impact a target at 1000 m (3281 ft). The approximate average change in velocity can be found at the halfway point, which is 1 s in this example. Gravity accelerates at 9.8 m/s^2 (32 ft/s^2). Therefore, even if a bullet is shot vertically, where 100% of the gravity is parallel to the trajectory, that would only equate to a final velocity change of 9.8 m/s (1 s × 9. 8m/s^2) (32 ft/s), which is a 2% change in velocity ((500 m/s) ÷ (9. 8m/s) ≈ 2%).

A 2% change in velocity causes gravity's perpendicular component to deflect the bullet from its trajectory for an additional 2% of the time, resulting in a 2% greater deflection. However, this 2% figure originally came from assuming an exactly vertical shot and 100% parallel gravity. Actual shots would have a much smaller parallel component. To find the parallel component, take the sine (sin) of the inclination. (See Image 178, Pg. 210.) (The perpendicular and parallel components do not add to 100%!)

- sin(0° to 15°) ≤ 0.25 ≤ 25% of gravity is parallel
- sin(15° to 30°) ≤ 0.5 ≤ 50% of gravity is parallel
- sin(30° to 40°) ≤ 0.65 ≤ 65% of gravity is parallel
- sin(45°) ≈ 0.7 = 70% of gravity is parallel
- sin(90°) = 0 = 0% of gravity is parallel

Therefore, if the inclination is less than 30°, then the parallel component can likely only change the bullet-drop by a fraction of a percent.

There are several ways to both measure the inclination to a target and to calculate the cosine component of that inclination. Many phone apps can detect an angle and provide the cosine value. (See Image 182, Pg. 213.) These work by aiming at the target and placing the phone on top of the inclined or declined scope. Similarly, rifles and scopes can have detached tools (i.e., a protractor attached to a level) or attached angle indicators. (See Image 183, Pg. 213.) Many laser rangefinders can also directly measure an angle without involving the rifle at all.

To make conversions easier and more precise, marksmen can use tools to convert the distance to the target to the equivalent flat-target distance with an angle-to-cosine conversion table online, or with an analog tool such as the Mil-dot Master. (See Image 177, Pg. 209.) The fastest but least accurate method of finding an angle to a target is when a marksman trains their intuition on the angle to quickly adjust their point-of-aim. This requires a lot of practice and reference points, as **estimating angles is not intuitive**.

19.b Change in Air Density with Change in Altitude

Air density decreases as altitude increases. (See Image 163, Pg. 190.) This means that bullets traveling upward face less resistance and experience less reduction in speed due to drag. For example, a bullet fired at a 45° angle

Tools That Measure Incline

Image 181: A clinometer is a handheld device that a marksman points at their target to read the incline angle.

Image 182: A level can be placed on the rifle. Many smartphones have access to a level app.

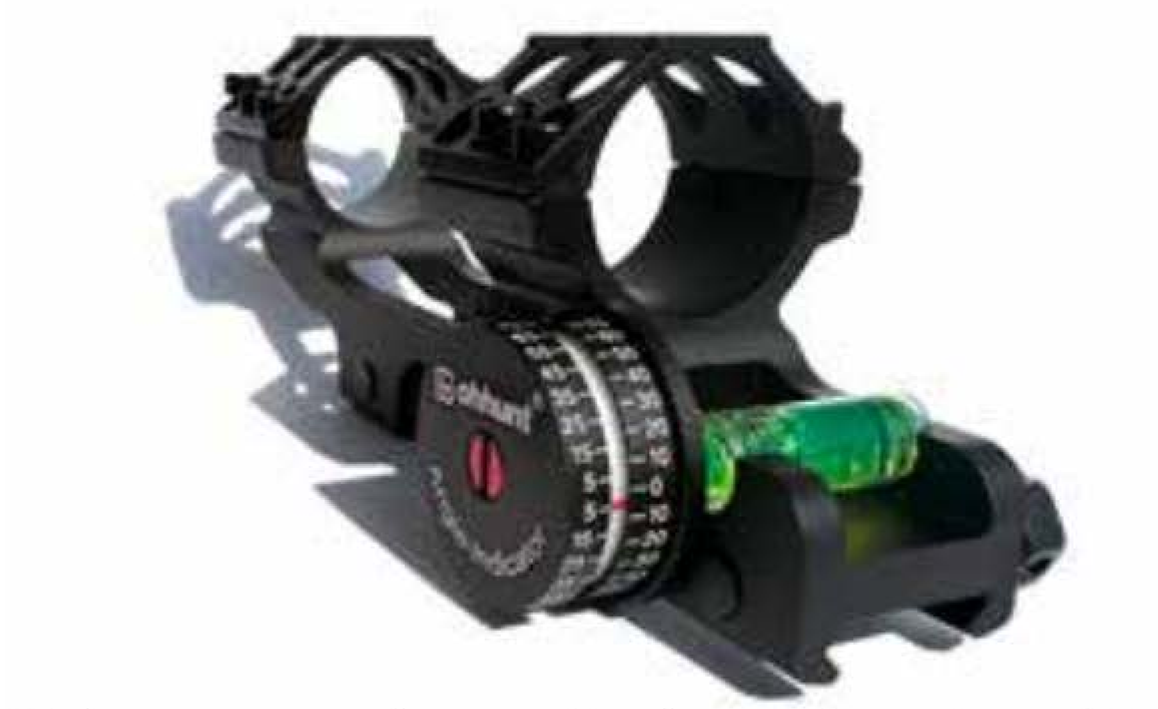
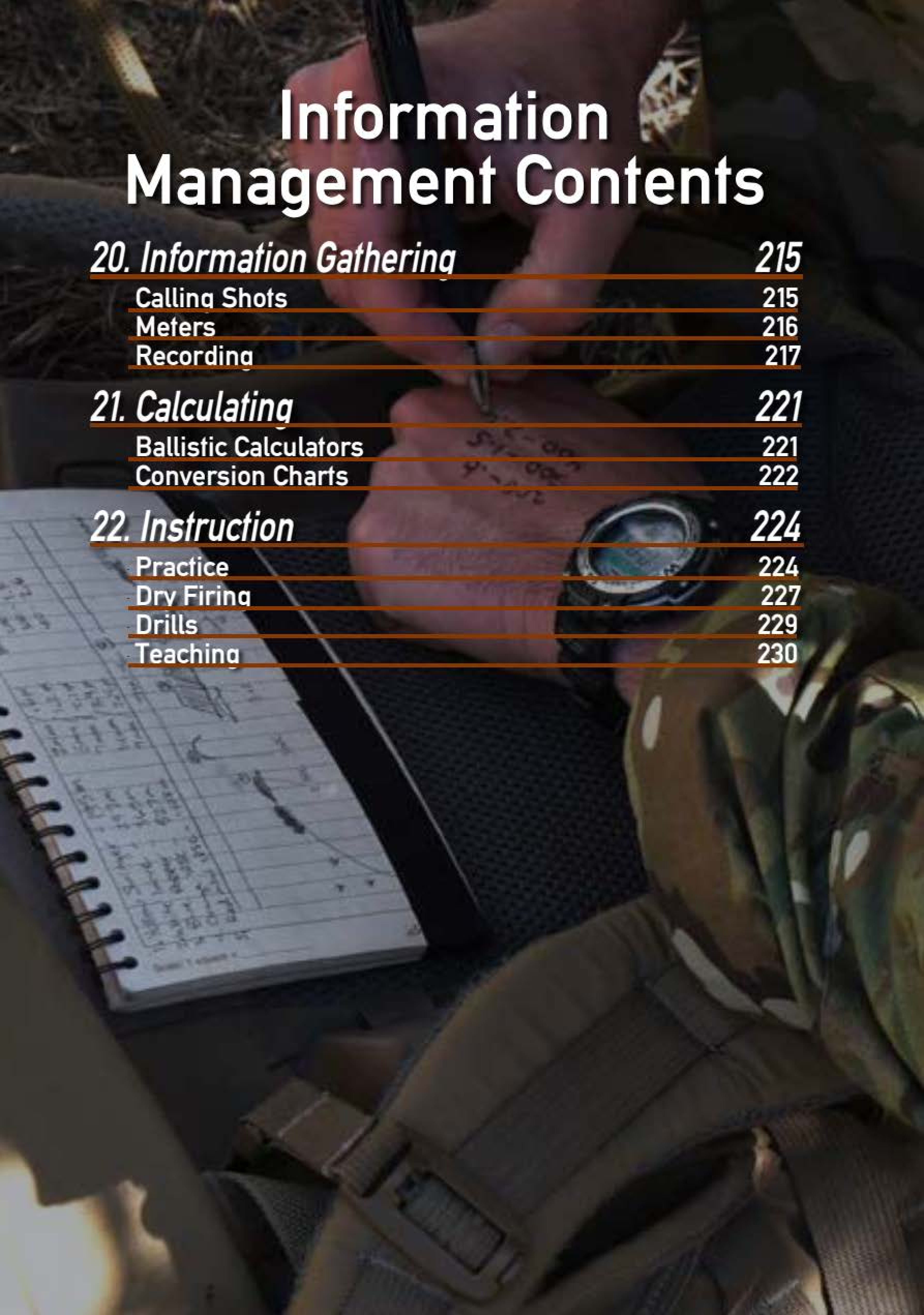


Image 183: This scope mount has an angle indicator (a.k.a., cosine angle indicator) attached to its left side. The the housing and mount rotate around the red line which always stays parallel to gravity. Currently the device shows a 5° decline.

toward a target 1,000 m (1,090 yd) away would face decreasing resistance as it travels, seeing a maximum density drop of 6% at its apex. Reduced air drag leads to less deceleration of the bullet and decreases the time that gravity has to affect its trajectory, resulting in less bullet-drop per unit distance. In contrast, shooting downward increases air density, which causes more drag and allows gravity to act on the bullet for a longer period. This results in greater bullet-drop per unit distance

That being said, the **change in air density is usually ignored** by everything but the most complicated ballistic calculators. This occurs because the change in velocity caused by varying air density nearly counteracts the change in velocity from gravity's parallel component (See Perpendicular and Parallel Components of Gravity, Pg. 209.) That is, these two effects act in opposition, and they tend to cancel each other out.



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Information Management

Information is the oxygen of the modern age.

—Ronald Reagan, 40th U.S. President

This section on information management aims to provide you with valuable insights into how you can gather, record, interpret, and learn the information you need to enhance your skills. This section is separate from the others because managing information isn't easily divided by skill level. Both beginner and expert marksmen need to continuously improve their information management skills to join the ranks of the best of the very best.

20. Information Gathering

There are two reasons why a marksman would want to gather information: in order to **reveal past mistakes** and to **predict future performance**. There are multiple types of information to consider gathering, such as information about the equipment, about the environment, and about the marksman's individual performance patterns.

While this section deals with information generally, some information-gathering processes have already been mentioned. For example, zeroing is the process of determining and eliminating the distance between the point-of-aim and the point-of-impact. (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.) And similarly, gathering information on wind is a huge part of being able to predict a bullet's left and right movement. (See Wind, Pg. 157.) The skills taught in those sections can be generalized to all information gathering.

20.a Calling Shots

"Calling shots" refers to the practice of predicting where a bullet has hit based on the sight picture at the moment of firing. After taking a shot, the marksman mentally notes or "calls" the expected point-of-impact without immediately looking at the target. Later, they check where the bullet actually landed and compare it to their prediction.

To better remember what their point-of-aim was after a shot is taken, a marksman makes a verbal prediction about where their bullet will impact on the target as specifically as possible (e.g., a corner or border). For example, a marksman may think to themself, "this shot will hit to the right of the bullseye," immediately before and after pulling the trigger. Also, maintaining a pause just after firing (i.e., follow-through) better allows the marksman to concentrate on recalling their point-of-aim and point-of-impact predictions.

Calling shots helps to:

- Encourage marksmen to be more deliberate when aligning the sights and aiming within the sight picture.
- Minimize flinching by diverting the marksman's attention from the recoil.
- Make the marksman better remember potential points-of-impact, which is vital when a bullet completely misses the intended target.
- Allow marksmen to develop and verbalize a consistent process into their shooting, making the process smoother and thereby faster overall.
- Force marksmen to immediately associate their sight pictures with success or failure, allowing marksmen to better replicate successful sight pictures and avoid repeating any unsuccessful ones.

Calling shots is especially vital in **team settings** where a separate person gives a point-of-aim to the marksman. For example, in marksman-and-spotter scenarios, it is crucial for a marksman to communicate aloud whether any mistaken shots were due to their own error (in any way!), or else due to events beyond their control.

If a marksman knows that the miss was their own fault, they try again with the same point-of-aim. They inform the spotter of this by saying "pulled [a shot]," or they can be more specific by indicating the direction of the error, such as "pulled up" or "pulled 15 cm (6 in) to the 12 o'clock." (The term "pulled" is shooting jargon to mean the trigger finger pulled the entire rifle, unintentionally shifting the point-of-aim. That said, some marksmen use "pulled" to refer to any shot that they caused to be bad.)

If the marksman believes that their point-of-aim was correct, they can provide the spotter with a general assessment, such as saying "good." And if they missed anyway, the fault may lie with the spotter giving the marksman an incorrect point-of-aim. Then the spotter must adjust or double-check the point-of-aim they had given to the marksman. The problem may also be with the equipment; for example, their rifle may have lost its zero.

In any case, if the marksman calls their shots, then the team better understands whose fault the miss was and therefore who must readjust.

20.b Meters

Many kinds of meters independent of the core rifle components have been discussed in this manual, to include those for: time (clocks or chronometer), muzzle velocity (ballistic chronograph), distance (laser rangefinders or telemeters), wind speed (anemometer), temperature (thermometer), humidity (hygrometer), air pressure (barometer), and slope (inclinometer). All of these meters are now commonly used as they have become electronic and compact.

If a marksman is considering buying or using a meter, they must consider a few things. First, they need to decide if the time spent learning how to use the meter and using it regularly is **worth the effort**. In other words, is the time investment beneficial? Ultimately, this decision is up to the individual marksman.

Second, they must weigh the improvement in accuracy or precision against the **cost of the meter**. The marksman is not interested in the meter's data for its own sake, rather what they want to know is exactly how that data can help them improve their skills. To compare different meters, the marksman must determine how much additional precision or accuracy each meter would offer relative to its cost, or even compare a meter against the option of not using a meter at all.

This analysis can quickly become complicated. For example, laser rangefinders greatly increase the accuracy of estimating distance. (See Estimation (Range and Wind) Uncertainty, Pg. 207.) However, laser rangefinders are expensive, standalone devices that can cost hundreds of dollars. In contrast, most hygrometers are built into weather meters, and cost almost no additional money. However, accurately knowing the humidity is unlikely to improve accuracy by more than a fraction of a percent.

20.c Recording

Data is useless if it is forgotten. Therefore, marksmen must develop a way to record and preserve whatever information they find useful or interesting. Common information that a marksman might find useful is wind data, climate data, equipment data, and data on themself such as the amount of sleep they got the previous night. (Fatigue and lack of sleep can lead to inadvertent errors and ultimately, missed shots.) There are too many kinds of data to list individually, but basically **every section in this book details some kind of useful data that can be recorded.**

Data can be recorded in various ways. The simplest way is binary, which only has two options. Any two mutually exclusive options work, such as: present or absent; hot or cold; energetic or tired; etc. Using a binary system is the fastest and easiest way to record data, and can be done with a checkbox. However, binary is not very exact, so most data is recorded with a specific number; for example, temperature is recorded with a number. Numbers are the best way to record data if computers are involved. A very technical approach is to create data tables. Here, each shot can be represented as a column, while the rows can consist of variables like elevation, windage, and the coordinates on the target.

In addition to binary and numerical systems, data can also be recorded using graphical representations. A marksman attempts to essentially draw a picture of what they see or detect. For example, for wind, a marksman may use arrows to show direction. The most common graphical representation is a paper target, where the paper itself becomes a record once shooting is finished. (See Image 187, Pg. 219.) It is also becoming far more common for people to video record marksmen as they shoot to detect problematic micro-movements, such as flinching from anticipating recoil. Video recording (especially in slow motion) is a great tool for improving one's skills. (See Image 190, Pg. 221.)

Traditionally, marksmen would compile their recordings in a **DOPE (Data On Previous Engagements)** book. (See Image 185, Pg. 219.) Such a book is very helpful because it can be formated with labels and grids to make data organization both fast and easy. However, DOPE books are not strictly necessary, and using a random piece of paper is still better than no recording at all. (See Image 184, Pg. 219.)

While the DOPE book is a general record, there are more specialized logs that the shooting community commonly also uses. For example, in a **shot-by-shot log**, marksmen record the date, time, weather conditions, ammunition specifics, sight settings, and the exact position of each shot on the target. Marksmen can add commentary next to each bullet marking, such as the elevation and windage used or if any mistakes were evident. Some marksmen also record environmental conditions such as wind speed and direction, temperature and humidity, altitude, light conditions, and even barometric pressure. A **barrel log** in contrast, is basically an account of the number and type of rounds fired through a barrel to determine if the barrel has degraded enough to require replacement.

In theory, these detailed records assist marksmen in analyzing their performance, tracking the effectiveness of adjustments to their equipment or technique, and adapting to different environmental conditions. However, the records must actually be used to be "useful." The most obvious way to use records is to find ways to improve. In contrast, many marksmen just

Recording Information

Image 184: This marksman records information on a used box of ammunition. He can transfer the information to a computer later.

Image 185: This marksman records on blank charts, printed on weatherproof paper and stored in a durable binder. **They were prepared**.

Image 186: While a marksman is shooting, an assistant or spotter can record information for later analysis.

Image 187: The easiest information to keep is used targets. Marksmen can simply keep them in a binder.

find recording to be an enjoyable exercise, and that is also a great reason to record. However, **without enjoyment or use, records are a waste of time**.

A marksman can better determine if they want to record data by starting slow and building up. For example, a marksman can start by only recording the impact location, and then add one data point to the record book each shooting session, instead of trying to record 20 data points from the start.

Tools that assist in recording are becoming more advanced by the day. One interesting analog tool, known as the Plot-o-Matic, involves using clear plastic sheets (e.g., Plexiglas or Lexan) placed over a target replica to compare their precision across different points-of-aim. Marksmen use one sheet per sight setting and overlay all the sheets, aligning each subsequent sheet based on the adjustments made to windage and elevation relative to the first shot group. When looking through the sheets, all shots on each layer converge into one shot-grouping. Digital apps, such as Shooting Companion: Plotter, perform the same function, but digitally.

Ballistic Calculators

Image 188: A U.S. Air Force Tech Sergeant uses a Kestrel-brand weather meter to take ground wind readings. Cheshnegirovo Air Base, Bulgaria, 12 May 2021. Readings. Modern ballistics calculators can be **downloaded as apps on a phone**.

Image 189: A U.S. Marine with 2nd Marine Division, checks his equipment before firing. Camp Lejeune, NC, 08 Mar 2021. He is holding a Kestrel-brand weather meter with a **built-in ballistic calculator**. These devices read the wind and climate data directly, and only require the user to input their rifle-system information.

Image 190: One Missouri Army National Guardsman shows another their shooting position on a phone. **Taking pictures and videos** of a marksman is a great way to analyze the shooting process and communicate any improvements.

21. Calculating

Any information that a marksman gathers must be converted into a usable form by performing calculations. The calculations can be done digitally with a computer or a ballistic calculator, or they can be done manually with the help of a conversion chart. Either way, a marksman must plan and prepare their method of calculation before a shooting session begins.

21.a Ballistic Calculators

Ballistic calculators predict the trajectory of bullets from the point of firing. Thereafter, **the user can receive an elevation hold from the calculator** that compensates for bullet-drop at whatever distance the target is along a bullet's trajectory. Depending on the calculator, the user may also receive a windage hold and an expected energy transfer from a bullet's impact. Therefore, ballistic calculators are indispensable tools for precision shooting beyond 300 m or yd.

To get these outputs, users must input several variables into the calculator, which may include but are not limited to: bullet weight, shape, muzzle velocity, and ballistic coefficient (a measure of air resistance efficiency); the target's distance and inclination; and environmental conditions such as wind speed, wind direction, temperature, humidity, and altitude.

Each ballistic calculator is programmed with proprietary formulas, so some brands are better than others. That being said, the technology is constantly improving, and all reputable brands are capable of accurately calculating well past 1000 m or yd.

Because the "calculator" is a program, many calculators are downloadable apps on phones. (See Image 188, Pg. 220.) Others are built into weather meters. (See Image 189, Pg. 220.) Downloaded app calculators are very cheap, as the marksman can use the phone they already own or instead can buy a disposable phone to solely serve as a calculator. However, marksmen still need to access reliable climate and wind information. This too can be found online. However, some marksmen prefer to not emit radio signals while they shoot. These marksmen require a portable weather meter, and so they may as well purchase one with a built-in ballistic calculator.

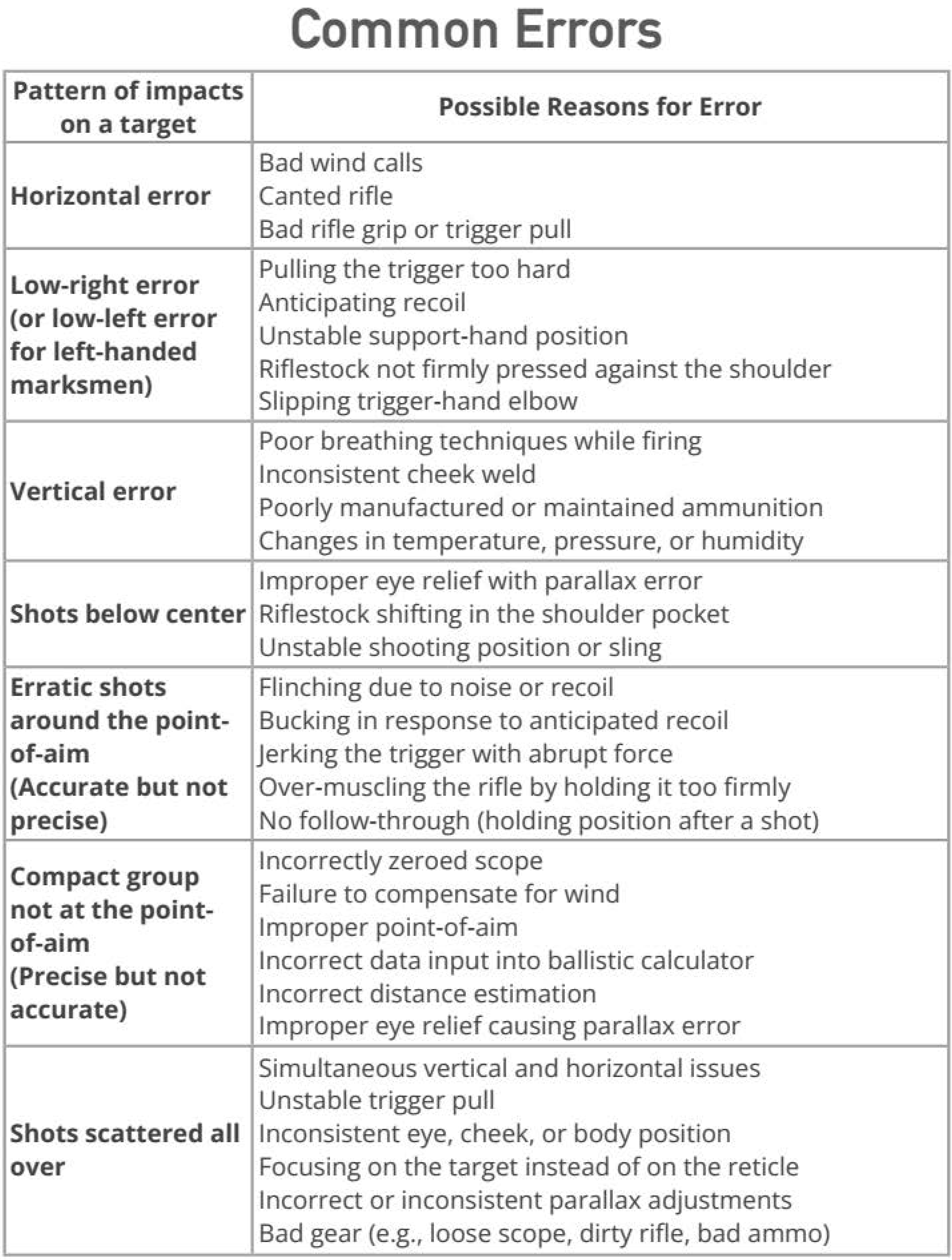
21.b Conversion Charts

In this manual, there has been a lot of talk about math and formulas. However, the math and formulas are only for preparation and for the sake of training. On the actual day of any important shooting, math is not performed. Instead, premade conversion charts are used to eliminate the chance of making errors. A conversion chart is very simple to use. It either has a single output derived from either one input (one-dimensional) (See Image 191, Pg. 223.) or two inputs (two-dimensional) (See Image 152, Pg. 174.). Marksmen simply select their inputs on the X and Y-axes, and follow the columns or rows to the resulting cell contents.

In fact, choosing printed conversion charts over electronics is not a matter of being old-fashioned; **it is far easier to reference inert, weatherproof sheets than to click tiny buttons in wet, cold, or dim conditions**.

The most in-depth charts already discussed in this manual are wind tables. (See Image 139, Pg. 160.) (See Image 140, Pg. 161.) (See Image 152, Pg. 174.) (See Image 153, Pg. 175.). Marksmen print out or write down wind tables, and for quick reference, keep the wind tables right next to their shooting position. (See Image 189, Pg. 220.)

However, charts have also been presented in other ways. For example a reticle is a chart of sorts that exists within a rifle (See Image 9, Pg. 19.), and when one is used alongside a Mildot Master (See Image 177, Pg. 209.), a marksman can determine their elevation hold without any electronics. Another example would be the chart of common errors that converts group characteristics into an area of improvement for the marksman. (See Image



Common Errors

Pattern of impacts on a target	Possible Reasons for Error
Horizontal error	Bad wind calls Canted rifle Bad rifle grip or trigger pull
Low-right error (or low-left error for left-handed marksmen)	Pulling the trigger too hard Anticipating recoil Unstable support-hand position Riflestock not firmly pressed against the shoulder Slipping trigger-hand elbow
Vertical error	Poor breathing techniques while firing Inconsistent cheek weld Poorly manufactured or maintained ammunition Changes in temperature, pressure, or humidity
Shots below center	Improper eye relief with parallax error Riflestock shifting in the shoulder pocket Unstable shooting position or sling
Erratic shots around the point-of-aim (Accurate but not precise)	Flinching due to noise or recoil Bucking in response to anticipated recoil Jerking the trigger with abrupt force Over-muscling the rifle by holding it too firmly No follow-through (holding position after a shot)
Compact group not at the point-of-aim (Precise but not accurate)	Incorrectly zeroed scope Failure to compensate for wind Improper point-of-aim Incorrect data input into ballistic calculator Incorrect distance estimation Improper eye relief causing parallax error
Shots scattered all over	Simultaneous vertical and horizontal issues Unstable trigger pull Inconsistent eye, cheek, or body position Focusing on the target instead of on the reticle Incorrect or inconsistent parallax adjustments Bad gear (e.g., loose scope, dirty rifle, bad ammo)

Image 191: A non-exhaustive list of common errors and their potential sources.

191, Pg. 223.) A final example would be a chart that can convert the movement of vegetation in the wind into an estimated wind speed. (See Image 158, Pg. 183.) **All of these charts are often used alongside electronic calculators, which are unable to make such abstract conversions.**

Image 192: A recon Marine with Force Reconnaissance Company, 13th Marine Expeditionary Unit, **examines his notepad to calculate** proper wind call adjustments. Kaneohe Bay, HI, 23 Aug 2013. He also has his elevation holds in his scope cap. (See Image 120, Pg. 139.)

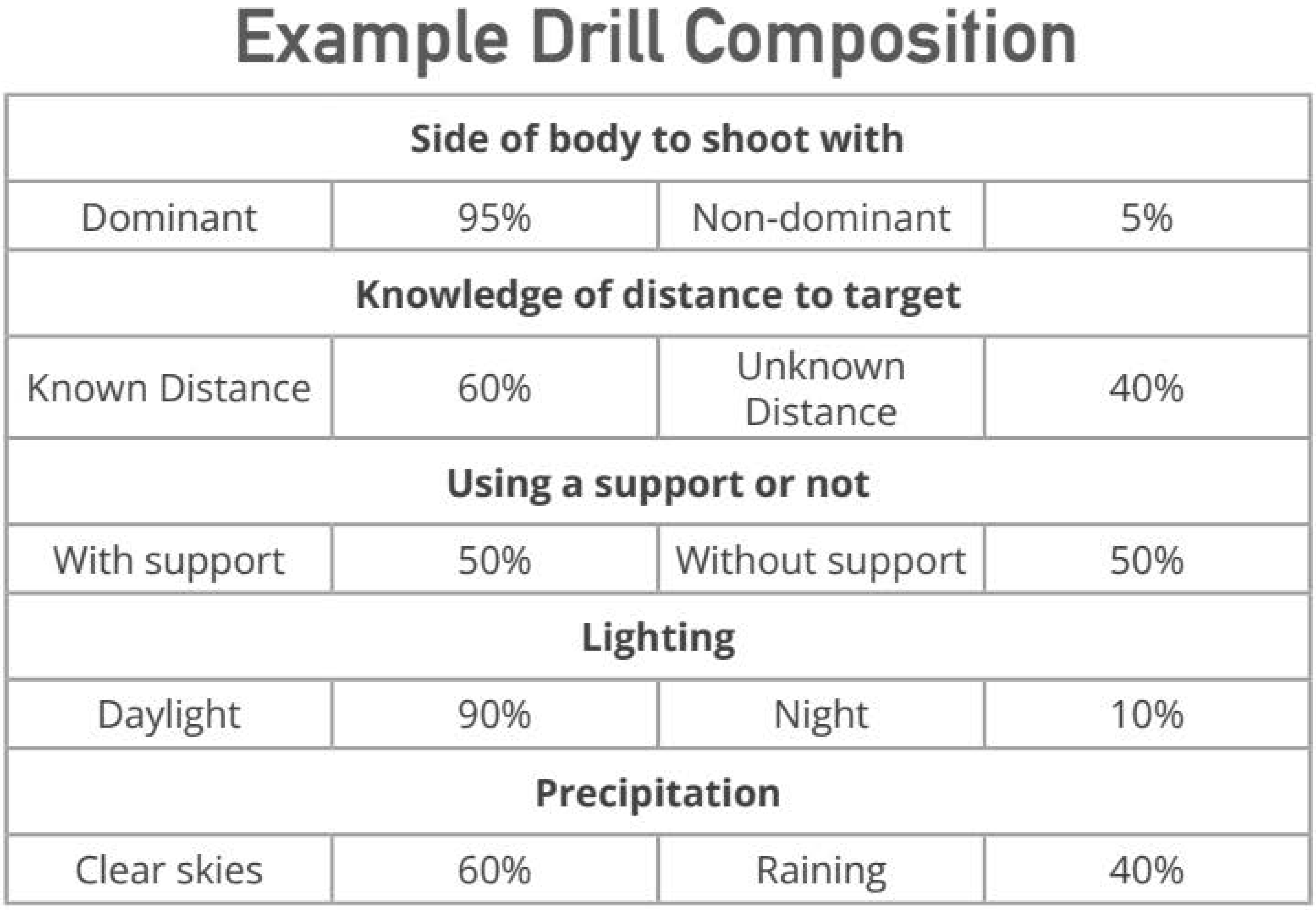
22. Instruction

Learning the basics of shooting may come naturally to some; however to become an expert marksman, training and practice are necessary. Just as with learning any skill, certain key principles apply, such as receiving feedback and isolating smaller skills. This section shows how those general skills of instruction apply to the specific discipline of long-range shooting.

22.a Practice

Effective practice takes time and cannot be achieved in just one session. It involves consistent and repetitive actions. To develop a good habit, an action must be repeated correctly at least ten times, and even more times if it is meant to replace a bad habit. Since building new habits takes time, ideally practice is done at a slower and more deliberate pace. For example, during a practice session, marksmen focus on taking their time to ensure they are in a good shooting position, rather than rushing into it.

Because practice must be done slowly, over an extended period, the first step to improving any skill through practice is to create a **structured training plan**. To create a training plan that is customized to a marksman or a group of marksmen, the first step is to determine what exactly needs improving. For example, if a marksman mostly has vertical errors in their



Example Drill Composition

Side of body to shoot with			
Dominant	95%	Non-dominant	5%
Knowledge of distance to target			
Known Distance	60%	Unknown Distance	40%
Using a support or not			
With support	50%	Without support	50%
Lighting			
Daylight	90%	Night	10%
Precipitation			
Clear skies	60%	Raining	40%

Image 193: This table shows an example drill composition.

shots, their problem is more likely to be caused by poor breathing techniques rather than canting the rifle. (See Image 191, Pg. 223.) When multiple errors are occurring, optimized training plans focus on areas where the learner is least skilled, as these areas typically offer the most room for improvement.

The skills that a marksman chooses to improve are ideally as specific as possible. For example, a marksman can improve the fastest by concentrating on mastering one particular rifle rather than shooting in general.

Some skills that need improvement may be obvious, while others might not be as clear. Additionally, the mistakes and details a marksman notices can change over time. Therefore, marksmen must continually update their training plans. Tracking progress is essential for identifying patterns and areas that need improvement. Shooting with a friend and exchanging feedback can also be beneficial, as individuals are often unaware of their own weaknesses.

Most marksmen create training plans that work on a diverse mix of skills, with some skills receiving more focus and time than others. While practicing one skill during a session is the most efficient use of time in the short term, it can lead to boredom. In contrast, happy learning is better learning, and varying practice routines keeps each session engaging. Therefore, it is important to do whatever makes a marksman eager to practice again and again.

A good planning tool for structuring a training plan is a **drill composition table**. (See Image 193, Pg. 225.) A drill composition table categorizes the various conditions a marksman might practice under, and assigns a percentage to each category. These percentages represent the ideal proportion of practice time that is ideally dedicated to each condition. By following the table, a marksman can balance their training and ensure that no skill is over or under-emphasized during practice.

Marksmen must assign a higher percentage of practice time both to skills that are important to master and those that are fast to learn. This greatly changes between different disciplines of shooting. For example, a tournament marksman might not need to practice shooting at night, while a hunter may not need to practice using a tripod.

To use a drill composition table, a marksman records each shooting session by adding a tally in the appropriate row and cell that describes the session. When planning future sessions, the marksman can then review these tallies to ensure their practice aligns with their designated percentages. If the tally ratios don't match their ideal percentages, the marksman can adjust upcoming sessions to focus more on under-practiced skills. This approach ensures that overall training maintains the intended balance.

Many marksmen often mistakenly prioritize precision over other crucial skills, such as shooting speed and adaptability. Take deer hunting for example; where a deer's heart at 100 m or yd allows for a roughly 0.5 mil radius of leeway from the center. Consequently, while shooting with 0.25 mil of precision is acceptable, it is not essential for successfully killing the deer. The more valuable skill to enhance would be reducing the time between spotting the deer and smoothly pulling the trigger.

In contrast, marksmen often under-prioritize practicing with external factors, such as rain or dusk. While removing these factors can be helpful for basic training, it doesn't accurately reflect real outdoor environments. For example, many marksmen train on ranges with minimal wind, allowing them to clearly see the effects of their adjustments without wind interference. However, when they hunt or compete in areas where wind is present, they may find themselves underprepared. To successfully make important shots in challenging environments, marksmen must practice in those same conditions.

Practice isn't limited to dedicated training sessions alone. Many marksmen also incorporate marksmanship exercises into their regular shooting activities. For example, many marksmen develop a routine that includes dry firing before all live-firing sessions (except for emergencies). (See Dry Firing,

Image 194: Multinational Soldiers from seven different countries participate in the Urban Sniper Course conducted by the International Special Training Center. Hammelburg, Germany, 04 May 2015. When teaching, shooting, and teaching how to shoot, it is vital to **set up robust communication** methods beforehand.

Pg. 227.) This helps calm them down and allows them to practice skills that need improvement without the added complexity of live ammunition. During live firing sessions, marksmen may record their mistakes in a logbook or with video, enabling them to review and analyze their performance later. These recordings can help marksmen determine the most effective way to proceed and any possible adjustments needed to their individual training plans.

22.b Dry Firing

Dry firing involves pulling the trigger of an unloaded firearm to practice as if it were loaded. (This does not harm modern centerfire rifles, unlike some rimfire weapons.) Following the rules of firearm safety is still paramount! (See Firearm Safety, Pg. 24.) By removing ammunition, marksmen can focus on their shooting for extended periods without worrying about either the cost or the danger of using live ammunition.

Of course, live firing is the gold standard for practice because it is the most realistic simulation of what a marksman is actually practicing for. However, **even if live-firing training were unlimited, marksmen would still practice dry firing**. This is because dry firing does not distract a marksman in the way that live firing does; that is, most importantly, dry firing has no recoil. Therefore, without being distracted by the explosion of gunpowder, a marksman can entirely focus on fixing their bad habits, such as flinching, anticipation, and using too much force on the trigger (a.k.a. “trigger jerk”).

More specifically, a clear sign of any effective shooting is when there is no deviation in the sight picture. However, during live firing, recoil always causes some deviation, making it difficult to determine whether a deviation is due to the marksman or the recoil. Dry firing eliminates external forces, ensuring that any deviation is solely caused by the marksman. This feedback enables marksmen to quickly identify and correct their mistakes.

To further enhance visibility of mistakes, marksmen can use a coin and a pencil. By placing a pencil in the muzzle and balancing a coin on top, marksmen can test their ability to keep the coin in place when pulling the trigger. If the coin remains balanced, it signifies that the marksman did not shift their rifle or sight picture while pulling the trigger. (See Image 198, Pg. 231.)

Just as for any other skill, **frequent practice leads to improved competency**. Dry firing can be done much more often and in more locations than live firing can, making it a great option for marksmen who cannot always live-fire. Another advantage of dry firing is its time efficiency. Marksmen can engage in multiple dry-firing sessions, up to fifty times, within a short period of 20 minutes without experiencing recoil fatigue. This time efficiency also makes dry firing an effective warm-up in high-stress situations. Target marksmen, hunters, and military snipers can dry fire at their targets when they assume their position, ensuring that their first live shot is as accurate as possible, potentially avoiding a cold-bore shot. (See Cold-Bore Shooting, Pg. 73.)

Perfect practice makes perfect, and a good setup for dry-firing practice is essential for realistically simulating the entire shooting process to get the best results from practice. For example, just as with live firing, it is crucial to establish a proper shooting position, maintain a sight picture, and control the trigger squeeze. Incorporating laser targets, laser guns, and dummy rounds into dry-fire training can make it more effective and enjoyable. Even acts such as replacing magazines, using the bolt, and resetting the trigger can be included in dry-firing practice. This **more complete immersion** allows the brain to adapt to the entire process, whether it is a dry or live-fire session, and helps the marksman avoid common mistakes that arise when transitioning from dry firing to live firing, such as changing a hand position or reloading.

In contrast, negligent or careless dry-fire practice can lead to poor fundamental skills and may be worse than no practice at all. Safety must always be a top priority, and all firearms must be treated as if they were loaded during dry firing. It is recommended to remove all ammunition from

Image 195: An assistant radio operator with Battalion Landing Team 3/5, 11th Marine Expeditionary Unit, dry-fires a Mark 13 sniper rifle. **Dry firing** is evident because there is no magazine. **The best practice is as real as possible**. Therefore, he is replicating the shooting scenario he is practicing for as closely as possible, including wearing full armor. USS John P. Murtha, Pacific Ocean, 08 May 2019.

the entire shooting area if possible and to be extra cautious when switching between live and dry firing. Most mistakes occur during this transition.

22.c Drills

A drill is a repetitive exercise focused on a specific task. Drills are highly effective for improving shooting skills because shooting is a composite of several small, distinct tasks. There are numerous shooting drills, and new ones are constantly being developed. This variety allows students to focus on and enhance the specific skills they need the most.

The most classic drill is the **ball and dummy drill**.(See Image 196, Pg. 231.) In this drill, the marksman assumes their shooting position with no ammunition or magazines. Out of the marksman's sight, an instructor or partner secretly loads the marksman's detachable magazine with a mix of live and dummy rounds so that the marksman cannot know the order of the rounds. The marksman then fires each round, treating all rounds as if they were live. This drill helps identify any flinching or anticipation issues, as any movement of the sight picture when "firing" a dummy round can only be self-caused due to a reaction to the recoil, flash, sound, or smoke.

A good drill that can improve shooting time is the **five-shot metronome drill**. (See Image 197, Pg. 231.) In this drill, the marksman uses a recording that emits a sound at regular time intervals, such as every 10 seconds. The marksman fires at each interval. If every shot is accurate and on time, the interval is shortened. Eventually, when the interval becomes too short to make accurate shots, the marksman gains insight into what is holding back their speed. This allows the marksman to focus on the problem area and improve.

The **manual-recoil drill** is another effective drill that can help correct a poor response to recoil. In this drill, the marksman dry-fires while a partner grabs the stock of the rifle and pushes it backwards into the marksman's shoulder. The amount of recoil applied by the partner is enough to allow the marksman to identify problems with their shooting position and ability to withstand recoil, but not so strong as to cause pain or injury.

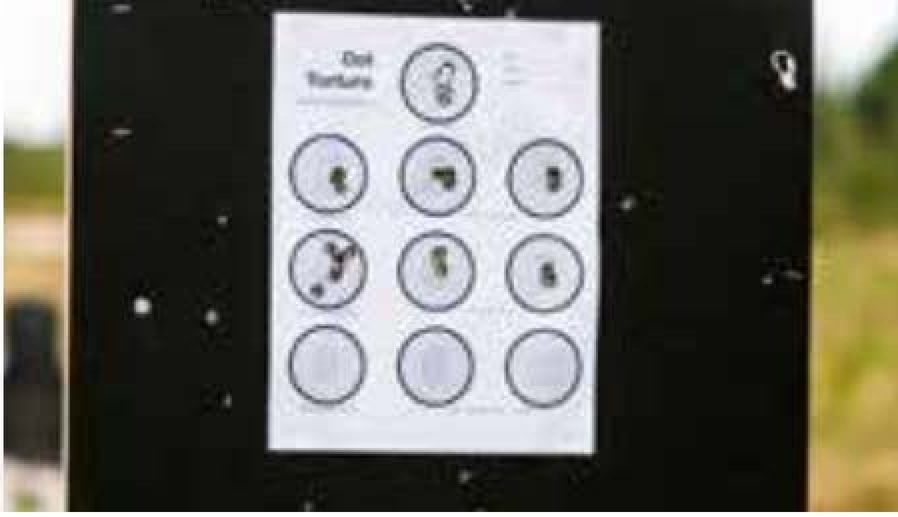
To prepare for real-life scenarios, marksmen benefit from incorporating drills that attempt to mimic their important shooting scenarios. For example, practicing hunters who hunt moving prey can set up multiple targets at different distances ranging from 50 to 400 m (55 to 438 yd) and practice shooting all of them in rapid succession to simulate a moving target. Hunters can also practice shooting from different positions (e.g., prone, kneeling, and standing) to simulate realistic conditions. Engaging in less stable positions, such as shooting at a target 400 m (438 yd) away while standing, can expose flaws in technique, while more stable positions (e.g., shooting at a target 50 m (55 yd) away while prone) can be useful for isolating specific skills to work on.

It is important to recognize that **no drill is effective if it is executed poorly**. For example, shooting drills can only begin after a marksman has properly grouped and zeroed their shots. (See Ensuring Accuracy (Grouping and Zeroing), Pg. 74.) Also, rushing a drill can lead to the formation of bad habits, such as rushing important shots or not fully forming good habits. To avoid rushing, it is always best to fully focus on and complete a smaller number of drills rather than attempting to half-heartedly complete a larger number of drills when practice time is limited.

22.d Teaching

Learning alongside another person is invaluable. Collective learning offers fresh perspectives, alternative viewpoints, physical assistance, and most importantly, **moral support**. Shooting with someone who has more experience is even more beneficial because they can elevate a marksman's skill level.

The key difference between a student-teacher relationship and a friendship is accountability. Mastering shooting is a mentally demanding process that



Example Drills

Image 196: The **ball and dummy drill** helps a marksman to overcome the anticipation of recoil. The drill has an assistant randomly load live and dummy (i.e., rubber) rounds into a magazine. The marksman then fires each round. Dummy rounds have no recoil, so if the sight picture moves when a dummy round is "fired," it is the marksman's fault and they must work on not moving the rifle. For safety, dummy rounds must be treated as if they were live rounds.

Image 197: The **metronome drill** helps a marksman to shoot faster and solidify good habits. The drill uses many small targets of identical size, such as on the pictured "Dot Torture" sheet. Marksmen fire a set number of rounds (e.g., 5) at each target within a set amount of time (e.g., 2 minutes). The time decreases after each target. If a marksman misses a single shot, they restart the drill. The goal is to get the time as low as possible without missing any shots.

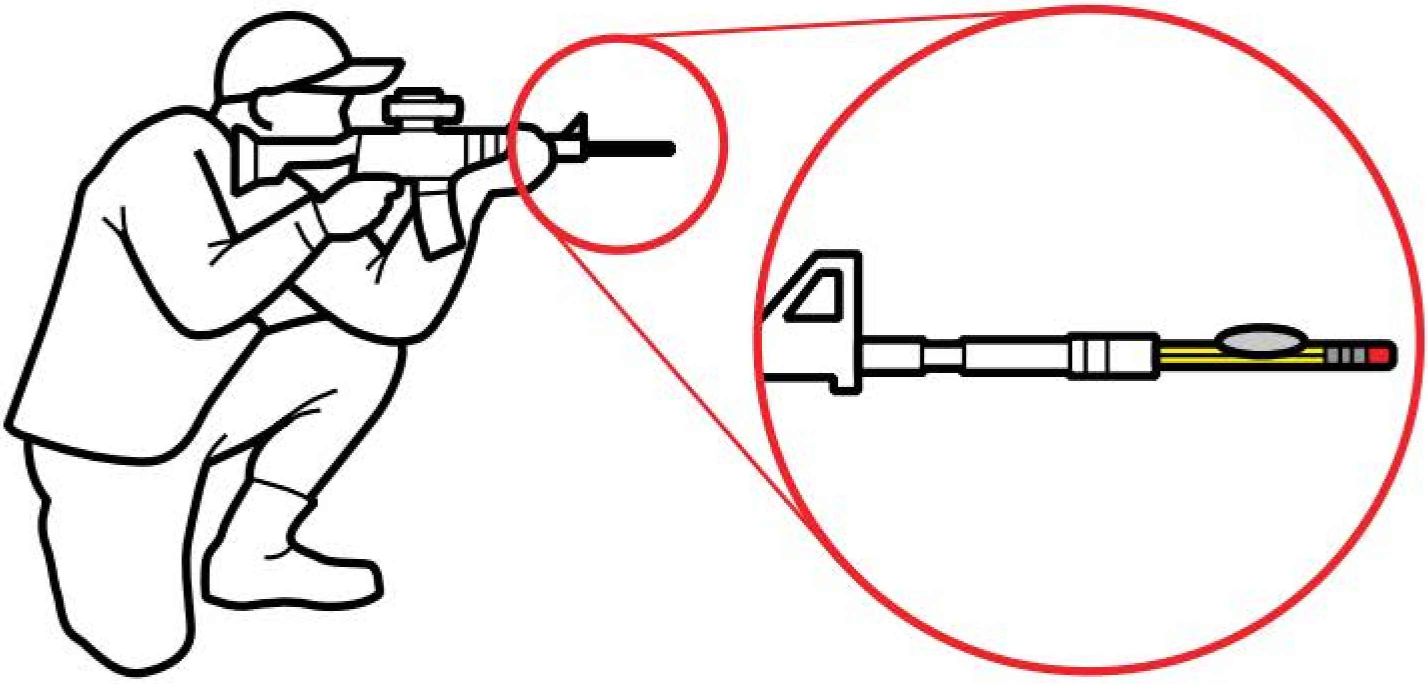


Image 198: To perform a **coin-balance drill**, a marksman places a pencil in the gun's muzzle and balances a coin on the pencil's end. The objective is to pull the trigger without dropping the coin. This drill can be practiced in any shooting position and offers various levels of difficulty. For example, using a hexagonal pencil is easier than using a round one, and balancing an eraser is easier than balancing a coin. Pencils are ideal because their tapered ends prevent them from slipping into the bore. It is unsafe to use anything that can fall into the bore. Always only point a gun in a safe direction, and never aim at anything that can't be shot.

requires effort. While a friend may not address a learner's laziness, a teacher must. A teacher reminds their student to call their shots, record data in their data log, and adhere to their training plan.

Teaching is not an innate ability; it must be learned. The most important teaching skill is asking questions of the student, as teachers must confirm their assumptions before suggesting changes. This ensures that the student's actions were indeed mistakes and not consciously made for a valid reason that the teacher may have overlooked. For example, if a student claims to be executing everything correctly, the teacher needs to consider the possibility of equipment error. The teacher may even swap positions with the student or provide the student with a different weapon to determine if the error is reproducible before offering guidance on how to improve. Of course, it is also essential for a student to avoid adopting their teacher's bad habits. Similarly, teachers must avoid instructing above their own skill level; a marksman who can only hit targets at 600 m or yd cannot effectively teach someone how to shoot accurately at 1,000 m or yd and beyond.

Asking questions is also crucial to determine a student's skill level. For example, a teacher can inquire about: the student's shooting history; any past difficulties that they may have faced; changes made to their equipment; or potential underlying issues such as poor eyesight.

It is essential for teachers to be attentive to signs of restlessness and fatigue, as **students in discomfort cannot learn at their best** and may end up developing bad habits. In order to maximize skill retention, individuals must take more frequent breaks when learning a skill compared to when using the skill. This is especially evident when teachers come to a shooting session with an arbitrary list of drills they want to finish by the end of the session. In order to finish the list, teachers often rush students faster than they are able to internalize the skill that the drill intends to teach. Rushed learning is very ineffective, and it is as pointless to move to a subsequent drill when the previous drill was not internalized as it is to build a house on a faulty foundation. Effective teachers only move on once they have confirmed that their students are ready to continue.

Additionally, stress can be very distracting, so it is important for teachers to adopt an **even, encouraging, and fair approach** when working with deadly weapons. That is, while punishment and derision can teach a student how to hit rock with a hammer, they are terrible teachers for complex systems. And if students are forced into stressful situations, they rightfully prioritize safety over learning.

Example Checklist

Gear
Weapon and ammo: ☐ Rifle case with rifle ☐ Ammunition specific to the rifles ☐ Magazines and speed loaders
Range gear: ☐ Ear protection ☐ Eye protection ☐ Targets and stands ☐ Stapler or tape ☐ Range bag ☐ Shooting mat ☐ Spotting scope or binoculars ☐ Cleaning kit ☐ Multi-tool or gun-specific tools ☐ Screwdriver set ☐ Backup batteries ☐ Rangefinder ☐ Pen and notepad ☐ First aid kit ☐ Firearm safety flag ☐ Gloves ☐ Sunscreen and hat ☐ Water and food ☐ Phone and photography or video gear
At the range
Preparation: ☐ Store unloaded firearms in a secure case until use ☐ Confirm the firearm is unloaded before handling ☐ Review the range's safety rules and procedures ☐ Verify range commands and signals ☐ Prepare a checklist of shooting drills
Setup: ☐ Set up targets at appropriate distances ☐ Load magazines with proper rounds ☐ Position shooting mat or bench ☐ Set up any shooting rests or bipods ☐ Prepare to take photos or videos
Shooting: ☐ Start with dry firing ☐ Practice proper shooting stance and grip ☐ Perform controlled shots, focusing on accuracy ☐ Adjust optics/sights as needed ☐ Regularly check targets for groupings and adjustments ☐ **Perform a prepared checklist of shooting drills**
Post-shooting session
Firearm check: ☐ Unload and clear firearms ☐ Inspect firearms for any wear, malfunctions, or issues ☐ Store firearms in cases
Pack up gear: ☐ Collect all spent casings ☐ Store used targets and dispose of trash ☐ Pack all tools and equipment ☐ Ensure nothing is left behind at the range
Post-shoot cleaning: ☐ Clean firearms thoroughly once home ☐ Clean any tools or gear as needed ☐ Restock ammunition and gear
Post-shoot review: ☐ Review your shooting performance and notes ☐ Plan any adjustments required for your next session

Image 199: **Checklists are ideal for complicated, repetitive tasks,** and can be as simple or as complicated as a marksman needs them to be.

In the long run, the best training plan and teacher aren't defined by how much they can teach in a single day, but by the knowledge learned by a student over time. To achieve this, it's crucial for teachers to keep shooting enjoyable to prevent student burnout. To make shooting fun, some marksmen enjoy buying new equipment, while others participate in shooting competitions. No matter the approach, **making learning as fun as possible is key**, even if not every part of the process can always be enjoyable.

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Appendices

The difference between ordinary and extraordinary is that little extra.
—Jimmy Johnson, head coach to the Miami Dolphins

23. Linear Distance

Linear distance is a measure of the length between two points in a straight line.

23.a Systems of Measure

There are two main systems-of-measurement used in the world of shooting, the **metric system** (formally known as the "International System of Units (SI)") and the **imperial system** (formally known as the "United States Customary System"). Ballistic charts, scopes, and other shooting accessories often use metric units for easier and more precise adjustments. However, it is common for United States civilians to use the imperial system.

Therefore, this manual presents both systems, usually starting with a unit in metric followed by the same unit converted to imperial within parentheses (e.g. 100 m (109 yd)). Metric units are first because metric is currently the global standard among militaries, including the United States, and it is slowly becoming the global standard for manufacturers as well.

23.b Meters (m) and Yards (yd)

In the metric system, the base unit for linear distance is the meter (m). The metric system follows a pattern where each related unit is a multiple of ten of the adjacent one. For example, 1 kilometer (km) is equal to 1,000 m, 1 m is equal to 100 centimeters (cm), and 1 cm is equal to 10 millimeters (mm).

The imperial units for linear distance include inches (in), feet (ft), yards (yd), and miles (mi). Unlike the metric system, the imperial system does not have a base unit. Because of this, conversions within the imperial system are not as straightforward as within the metric system; 1 mi is equal to 1,760 yd or 5,280 ft, 1 yd is equal to 3 ft, 1 ft is equal to 12 in.

Converting between units has become much easier with the widespread availability of calculators and smartphones. Although mostly non-urgent, in situations where the internet is not accessible, conversions between units can be addressed by printing and using conversion tables. (See Conversion Charts, Pg. 222.) However, there is a simple trick for converting between meters and yards. 1 m is equivalent to 39.37 in (1.09 yd), while 1 yd is equivalent to 36 in, which means that a meter is approximately 10% longer than a yard. A helpful way to remember this is that the capital letter “M” has more lines and if all the lines were put together to make a straight line, “M” makes a longer straight line than “Y.”

Alternatively, for all estimates where a 10% difference is insignificant, meters and yards can be used synonymously. In fact, this manual often uses the term “m or yd” for estimates where the 10% distinction is unimportant or irrelevant and the point being made would be true regardless of the unit being meters or yards.

23.c Caliber

Firearm caliber refers to the internal diameter of a firearm’s barrel bore, and it serves as a measure of linear distance. In a rifled barrel, the distance is measured between opposing lands (the high part of rifling) or between opposing grooves (the low part of rifling). Stating the groove measurement is common in cartridge designations originating in the United States, while stating the land measurement is more common elsewhere.

Caliber can be expressed in either inches (in), as part of the imperial system, or in millimeters (mm), as part of the metric system. In the imperial system, caliber is typically denoted as a decimal, followed by the word “caliber” or its abbreviation “cal.” For example, a firearm with a “.45 caliber” (explicitly without a preceding zero) possesses a barrel diameter of approximately 0.45 in, and has been designed to fire bullets with a diameter close to 0.45 in. On the other hand, in the metric system, caliber is usually represented by its linear measurement, followed by the abbreviation for millimeter “mm.” For example, a 9-mm firearm has a barrel diameter of 9 mm and is designed to fire bullets with a diameter of 9 mm. With that said, some renowned cartridges and bullets are known by both measurements, such as the 5.56 NATO or .223 Remington (5.56 mm equals 0.223 in).

It is important to acknowledge that the nominal caliber can differ from the actual caliber of the firearm. For example, a firearm may be classified as a 30-caliber rifle (i.e., 0.30 in or 7.6 mm), but there can be significant variations in nominal bullet and bore dimensions. Specifically, firearms and projectiles chambered in 303 British are often labeled as “.30-caliber” alongside many U.S. “30-caliber” cartridges, despite utilizing bullets with diameters ranging from .308 to .312 in. (7.82 to 7.92 mm).

24. Angular Distance

Angular distance is a measure of how much an object rotates. For example, if a full rotation is 1 unit of angular distance, then a half-rotation would be 0.5 units of angular distance, and a quarter rotation would be 0.25 units of angular distance. The number of units in a circle is arbitrary and does not have to be 1. For example, if a circle is divided into 4 units of angular distance, then a quarter rotation would cover 1 unit of angular distance. When a circle's circumference is divided into 360 units, each unit is called a "degree." That is, a rotation of 1/360 on a circle is rotation of 1 degree.

A helpful way to understand this concept is by considering slices of pizza. Someone ordering pizza would not say, "3 inches of pizza please," specifying the distance in linear terms. They would instead say, "one slice of pizza please." That is, with 8 slices typically cut into any standard-sized pizza this is one-eighth, or 45°, of the round pizza. Where would one even begin to measure 3 inches of pizza? Using angular distance to measure a circle is unambiguous.

Angular measurements are crucial in ballistics because many concepts of shooting require rotating a specific, quantifiable amount. For example, when adjusting a scope on a rifle, the adjustment effectively rotates the scope's sight picture relative to the rifle. Similarly, when a marksman adjusts their aim to engage a different target, they rotate their body.

A marksman's reticle in their scope serves as their angular measurement tool. Scopes typically employ one of two systems: minutes-of-angle (MOA) or milliradians (mils; mRads). Similar to units of linear distance, these two units can be directly converted. These systems are further explained in the following sections.

One way to understand how reticles measure angular distance is to observe that larger objects farther away can appear the same size in the scope as smaller objects that are closer. That is, as an object moves further from the observer, it appears smaller because it occupies a smaller percentage of the observer's field-of-view. For example, a boulder measuring 4 m (4.4 yd) in width appears to occupy approximately 2° of the marksman's field-of-view when positioned 100 m (109 yd) away. However, if the same boulder were placed 200 m (219 yd) away, it would then occupy approximately 1° of the marksman's field-of-view.

Angular Distance

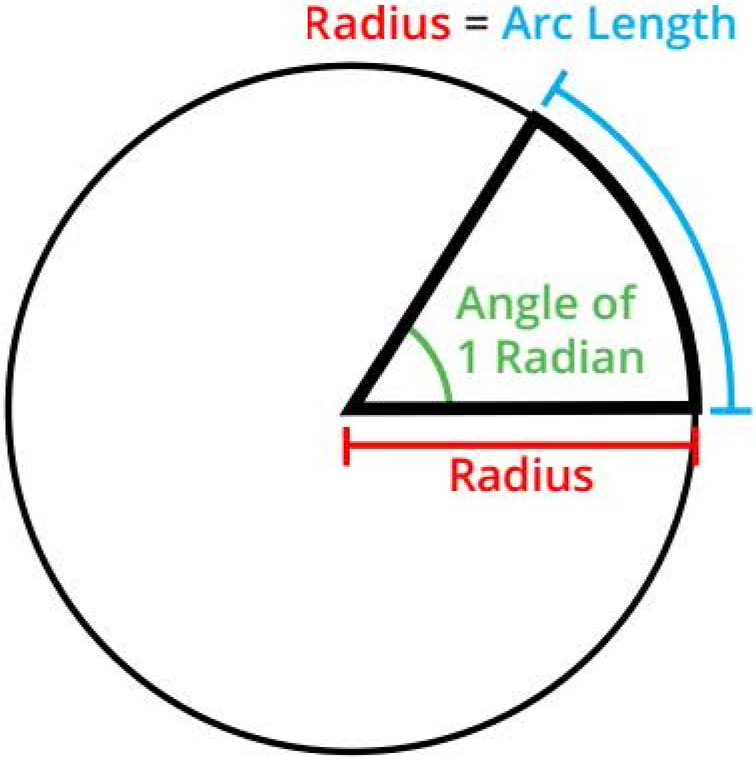
Radius = Arc Length
Angle of
1 Radian
Radius

Image 200: “Angular distance” is a way to say “angle.” An angle of 1 radian (equal to 57.3 degrees) is defined by having an arc length that is equal in length to the radius of the circle. 1 radian = 1000 milliradians (a.k.a. “mils” or “mrads”).

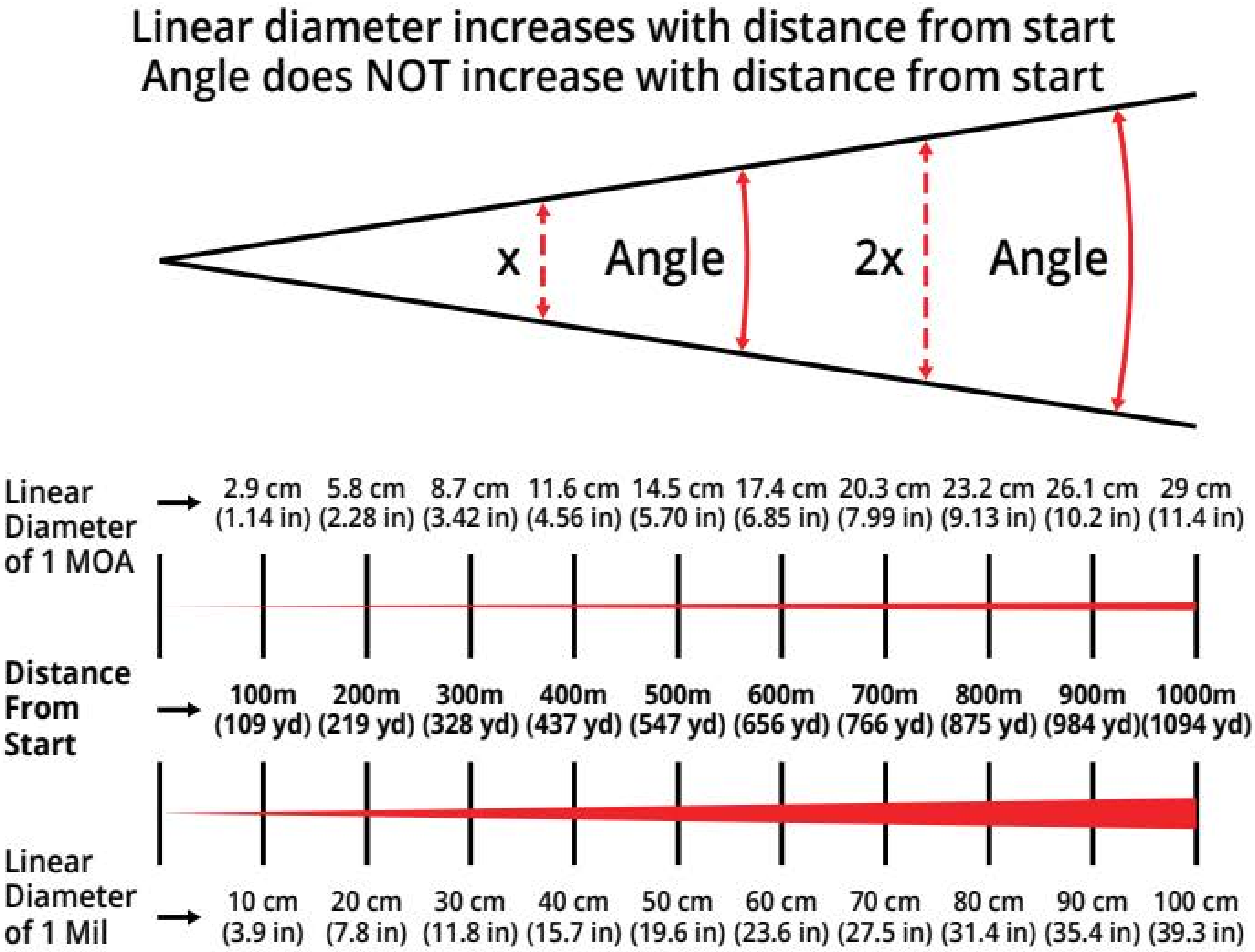
Linear diameter increases with distance from start
Angle does NOT increase with distance from start
x
Angle
2x
Angle
Linear Diameter of 1 MOA
2.9 cm (1.14 in)
5.8 cm (2.28 in)
8.7 cm (3.42 in)
11.6 cm (4.56 in)
14.5 cm (5.70 in)
17.4 cm (6.85 in)
20.3 cm (7.99 in)
23.2 cm (9.13 in)
26.1 cm (10.2 in)
29 cm (11.4 in)
Distance From Start
100m (109 yd)
200m (219 yd)
300m (328 yd)
400m (437 yd)
500m (547 yd)
600m (656 yd)
700m (766 yd)
800m (875 yd)
900m (984 yd)
1000m (1094 yd)
Linear Diameter of 1 Mil
10 cm (3.9 in)
20 cm (7.8 in)
30 cm (11.8 in)
40 cm (15.7 in)
50 cm (19.6 in)
60 cm (23.6 in)
70 cm (27.5 in)
80 cm (31.4 in)
90 cm (35.4 in)
100 cm (39.3 in)

Image 201: Angular units, such as milliradians (mils) and minutes-of-angle (MOA), measure how wide or narrow an angle is. An angle measures a set percent of a circle, so as the circle becomes larger, the linear diameter of an angle may increase but the angle itself remains the same. This image gives the correct numbers for 1 MOA and 1 mil; however, the red triangles are enlarged to an angle of approximately 30 MOA and 30 mils so that they are clearly visible.

24.a Minute of Angle (MOA)

A complete circle consists of 360° or 360 degrees. (See Image 98, Pg. 113.) Under the minute-of-angle measurement system, each degree consists of 60 "minutes," and each minute consists of 60 "seconds." (This would be like a clock with 360 hours.) As a result, a circle is composed of 21,600 minute slices and 1,296,000 second slices. So, a minute-of-angle (MOA), also known as a minute-of-arc, arcminute, and arcmin, represents 1/21,600th of the circle surrounding the observer. Degrees, minutes, and seconds are associated with the imperial system only because they are not an official part of the metric system; however, minutes-of-angle work equally well alongside both systems.

24.b Inches Per Hundred Yards (IPHY)

By pure coincidence, a circle with a radius of 100 yd has a circumference of 22,619 in. This is very close to the aforementioned 21,000 minutes in a circle's circumference. In fact, dividing 21,600 minutes by 22,619 equals approximately 1.047 minutes per inch. Therefore, many marksmen approximate that at 100 yd (91 m), 1 MOA is equivalent to 1 in.

The rounded ratio of 1 minute per inch goes by another name, "inches per hundred yards" (IPHY). IPHY is a third angular measure alongside milliradians and minutes-of-angle. Because 1 MOA represents 1.047 inches per 100 yards, 1 IPHY is about 5% smaller than 1 MOA. There are 22,619 IPHY slices in a circle.

However, because people prefer round numbers, many marksmen and manufacturers have conflated IPHY and MOA. Even the renowned scope manufacturer Leupold makes no mention of this discrepancy between the IPHY and MOA on their official website. They only state, their "riflescopes are available with MOA (1 MOA = 1 inch at 100 yd (2.5cm at 91 m)) adjustments and reticles." This description is incorrect, 1 MOA = 1.047 in at 100 yd.

While Leupold is undoubtedly aware that their information is technically incorrect, it still remains unclear which of the two measurement systems (MOA or IPHY) their scopes actually use. Leupold can continue to sell with ambiguous terms for two reasons. First, the 0.047 (i.e., 5%) difference only matters to extremely precise marksmen. This is because the fractional differences only add up to a significant variation at extremely long distances, 1,000 yd (910 m), for example. The difference between a 40 MOA and a 40 IPHY adjustment at 1,000 yd (910 m) is only 1.88 in (0.047 in × 40).

The second reason is that clicks rarely exactly match the stated measurement anyway. Marksmen must independently determine how much a click on their scope turret actually moves their reticle. For example, one click on a reticle may be advertised as rotating a turret by 1 MOA, but instead actually move the reticle by 0.98 MOA or 1.02 MOA. Part of setting up a scope is determining how much a click on each turret actually moves the reticle.

24.c Milliradian (Mil a.k.a. MRAD)

Under the milliradian measurement system, a circle's circumference is 6.283 (i.e., 2π) radians or 6,283 (i.e., 2000π) milliradians (mils, mRads), where 1 radian is equal to the radius of the circle.

So, if two marksmen fire two rounds at an angular distance of 1 radian, the bullets form an approximate equilateral triangle with the marksmen. Similarly, if the marksmen fire at a distance of 1 mil apart from one another, the distance between the bullets is approximately equal to 1/1,000th of the distance they have traveled. Therefore bullets fired 1 milliradian apart would be 1 yd apart at 1,000 yd, and they would be 1 m apart at 1,000 m.

This seemingly straightforward relationship becomes more complex when marksmen consider that there are different legal definitions for the number of mils in a circle. The U.S. military and NATO often divide a circle into 6,400 mils, whereas Russia and some European countries may divide a circle into 6,000 mils.

Further complicating any conversions, the approximately 2% difference between 6,283 (the circumference of a circle in mils) and the commonly used 6,400 mils, is often within manufacturer tolerances, making it difficult to determine which standard a particular nation or manufacturer uses based solely on equipment. In other words, a scope claiming to adhere to one standard may actually be adhering to another.

Irrespective of the specific standard used, many mil-scopes are manufactured with adjustments in 0.1 (1/10th) mil increments, though some scopes offer .05-mil adjustments. One-tenth of a mil represents an angle that measures exactly 1 cm at 100 m, 20 cm at 2,000 m, 3.6 in at 1,000 yd, etc. Similarly, half a tenth of a mil (i.e., 1/20 mils) would be half that.

24.d Comparing and Converting MOA and Mil

Both MOA and mil measurement systems are equally effective in describing angular distance, with neither being more or less precise than the other. Some advocates note that 1 MOA is smaller than 1 mil; however, this difference is moot since one-tenth of a mil is smaller than 1 MOA. Regardless, once someone is familiar with one system, there is no advantage to switching to the other system unless they need to use equipment that is only available in that alternative system.

With that said, sometimes a marksman still needs to convert between the MOA and mil standards. A common scenario requiring conversion is when marksmen need to input a wind call they learned from an MOA system into their mil scope.

Conversions are often approximated, due to the lack of precision in these measurements. For example, according to the mathematical definitions presented above, a circle contains 21,600 MOA and 6,283 mils, resulting in 3.44 MOA per mil. However, if someone labeled IPHY units as MOA units and used NATO-defined mils instead of mathematical mils, a circle would have 22,619 IPHY and 6,400 NATO mils respectively, resulting in 3.53 “MOA” per “mil.” So, in making things less complex, when the exact nature of the units is unknown, **an approximated conversion of 3.5 MOA to 1 mil is fine**.

Despite the ease of conversion by simply multiplying mils by 3.5 to obtain MOA, converting between the two systems can still generate numerous errors. So, it is best to use the unit of measurement favored by the marksman’s community. The mil measurement system is supported by more advanced equipment and is therefore preferred by the international community, the U.S. military, and most competitive shooting participants. The primary group still using MOA is North American civilians, although it remains a sizable group. Regardless of the unit of measurement used, it is crucial to employ the same unit for both a scope’s turrets and reticle to avoid any conversion errors.

25. Other Measurements

To become an expert marksman, it is helpful to understand the physics of a bullet in motion. To that end, this appendix describes fundamental principles that affect bullet behavior: speed, velocity, mass, weight, force, pressure, work, energy, and momentum.

These topics might seem daunting at first, as they involve substantial scientific concepts. However, readers do not need an advanced degree in physics to understand and apply the knowledge in this book, as only basic concepts are required. That said, for those interested in a deeper exploration of the physics of shooting in more detail, Khan Academy offers free online video courses on the subject.

25.a Speed and Velocity

Movement refers to the change in position of an object over time. This can occur in various ways, such as linear motion along a straight path or rotational motion around a fixed point. Movement has two measures: speed and velocity.

Speed is a measure of how quickly an object moves or the rate at which it covers distance. Formally, speed is calculated as distance over time and is denoted in units like meters per second (m/s), kilometers per hour (km/h), miles per hour (mi/h), or feet per second (ft/s). For example, if a car covers 100 km (62 mi) in 2 hours, its speed is 50 km/h (31 mi/h). Speed is a scalar quantity, meaning it only describes how much an object moves without regard to direction.

- *Speed* = *Change in Distance* ÷ *Change in Time*

Velocity, on the other hand, is a vector quantity, which means it includes both the magnitude and direction of an object's movement. While speed measures how fast an object is moving, velocity also specifies the direction of its movement. For example, if a car is traveling at 50 km/h eastward, its velocity is 50 km/h east. The distinction between speed and velocity is crucial in scenarios where direction affects the outcome of the movement.

- *Velocity* = (*Change in Distance* ÷ *Change in Time*) in a *Specified Direction*

In ballistics, speed and velocity are often used interchangeably because the assumed direction is typically from the marksman to the target. However, there are scenarios where a distinction between the two is necessary such as when adding two speeds together. For example, a marksman may fire a bullet at 4,000 km/h (2,490 mi/h) (speed 1) from a truck traveling at 40 km/h (25 mi/h) (speed 2). If both are moving north, the two speeds are added together, and the bullet's speed relative to the ground would be 4,040 km/h (2,510 mi/h). Conversely, if the truck is moving south while the bullet moves north, the truck's speed would be subtracted from the bullet's velocity, which would be 3,960 km/h (2,460 mi/h).

Acceleration is the term used to describe the change in velocity. Like velocity, acceleration is also a vector quantity which must include a direction. Acceleration is typically measured in units such as meters per second squared

(m/s^2), kilometers per hour squared (km/h^2), miles per hour squared (mi/h^2), or feet per second squared (ft/s^2). In the case of bullets, gravity acts as an acceleration force, causing them to fall downwards at a rate of 9.8 m/s^2 (32 ft/s^2). This means that every second, an object's speed towards the ground becomes 9.8 m/s (32 ft/s) faster.

- *Acceleration* = (*Change in Velocity* ÷ *Change in Time*) in a *Specified Direction*

25.b Mass and Weight

Mass and weight are two distinct properties of matter. Mass represents the amount of matter in an object and remains constant regardless of its location in the universe. It is measured in grams (g) or kilograms (kg) in the metric system, and in pounds (lb) in the imperial system. The conversion factor between kilograms and pounds is 0.454 kg per lb and 2.20 lbs per kg.

On the other hand, weight is the gravitational force exerted on an object and depends on the gravitational field the object is in. It is a vector quantity, and it can be calculated using the following formula:

- *Weight* = *Mass* × *Gravity*

Consequently, an object's weight varies according to the local gravity. For example, an object weighs less on the Moon's surface than on Earth's because the Moon has a weaker gravitational pull.

In fact, the same object can weigh different amounts on Earth because different locations on Earth have different levels of gravity. This occurs because gravity is stronger closer to the Earth's center (i.e., low altitude) and at the poles where centrifugal pseudo-force is not "pushing" objects away from the Earth's surface.

Earth has a maximum variation in its gravitational acceleration of approximately 0.7%. The lowest value is found at Mount Nevado Huascarán in Peru at 9.76 m/s^2 (384 in/s^2), while the highest gravity is at the surface of the Arctic Ocean at 9.83 m/s^2 (387 in/s^2).

Differences in weight can cause serious problems in international trade, where for example a tonne of sugar in Brazil (more gravity) would contain less mass than a tonne of sugar in Canada (less gravity). Therefore, international trade is nominally conducted in units of mass, such as the kilogram. In practice, most scales measure force, or weight, making the distinction moot. However, this is why units of weight and mass are commonly confused with each other.

The appropriate metric unit for weight is the newton (N), which is also the unit of force. However, the pound, the imperial unit for weight, creates further confusion as it can be used to measure both mass and force. The pound-mass (lbm) represents mass, while the pound-force (lbf) measures force. 1 lbm under the influence of Earth's gravitational pull produces 1 lbf. Nonetheless, this distinction is seldom made, as the metric system is preferred for precise measurements anyway.

Apart from grams and pounds, there is a commonly used third unit of mass known as "grains." This unit is the global industry standard for measuring the mass of gunpowder and bullets. There are 15.43 grains in 1 g and 7,000 grains in 1 lb. However, this is also slowly changing to the metric gram and milligram.

25.c Force and Pressure

In ballistics, the force of a bullet represents its ability to propel itself through air or target material. The unit-of-force is expressed by newtons (N) in the International System of Units (SI). The formula for force is:

- $Force = (Mass \times Acceleration)$

Since force is determined by multiplying mass by acceleration, the total force of a large object accelerating slowly can be equal to that of a small object accelerating quickly. In cases where an object experiences force, it is due to another object applying force to it. For example, bullets experience force that propels them forward because gas spends its force pushing the bullet.

Additionally, any interaction involving force also involves an equal reaction. So, when one object accelerates another, the second object decelerates (i.e., accelerates in the opposite direction) the first object. Designing bullets involves ensuring that they maintain their force (i.e., accelerated) through air but expend their force upon reaching solid targets.

Pressure is determined by dividing force by area and is measured in pascals (Pa). The formula for pressure is:

- $Pressure = (Force \div Area)$

Pressure is relevant in several aspects of shooting, particularly in bullet design. For example, a bullet with a smaller tip applies more pressure to a target with the same amount of force. The level of pressure determines whether force causes an object to deform or break. Armor-piercing rounds, for example, retain their pointed shape upon impact, applying greater pressure than fragmentation rounds, which disperse rapidly upon contact with the target (i.e., have a larger area of impact). Therefore, using the same amount of force from the gunpowder but over a smaller area (the tip of an armor-piercing round) allows for easier breaking and penetration of target objects.

The downside of high-pressure rounds is that they are bad at transferring energy. Armor-piercing bullets are likely to shoot right through a target, retaining a substantial amount of their energy, whereas a lower-pressure, fragmentation bullet (e.g., a soft-point or hollow-point bullet) would transfer all of its energy to the target, causing considerably more damage.

25.d Work and Energy

Work is a concept in physics that helps to understand how things move. Work is most often described through its formula:

- $Work = Force \times Distance$

That is, work is defined as the force that is applied over a distance. For example, when a bullet is fired from a gun, the explosion inside the gun creates a force that pushes the bullet forward. The exploding gas only applies force to the bullet while the bullet is in the barrel, so it can apply its force over a longer distance (i.e., do more work) in a longer barrel than a shorter one.

Energy is a related concept in physics that describes work that can be done, but is not currently being done. In other words, energy is the ability to do work (a.k.a. potential work, or stored work). For example, gunpowder possesses energy because it can do work in the future. In contrast, exploding gases are an example of work being done (i.e., transferring their energy to the bullet).

There are a few equivalent units for both work and energy. For example, in the metric system, one unit of work is a newton-meter (N × m). The newton-meter is equal to the joule (J), which is a unit of energy. (That is, 1 J is equal to the amount of work done when a force of 1 N displaces a mass by 1 m.) The imperial unit for work and energy is the foot-pound (ft × lb), which is calculated by multiplying a foot by the pound-mass.

Work and energy are also equal to mass times velocity squared. To prove this, the previous formula can be rearranged into the following:

- $Work = Force \times Distance$
- $Work = Acceleration \times Mass \times Distance$
- $Work = (Distance \div Time^2) \times Mass \times Distance$
- $Work = (Distance^2 \div Time^2) \times Mass$
- $Work = Velocity^2 \times Mass$

This has two implications. First, energy and work are directly proportional to the mass of the object. This means that objects with more mass require more energy to move or stop. Second, energy and work are proportional to the square of the velocity. This implies that even a small increase in the velocity of an object results in a much larger increase in the energy contained within it. For example, doubling the speed of a bullet requires four times the kinetic energy to be applied to it, and subsequently, the bullet can do four times the amount of work on the target.

The "conservation of energy" is a key principle stating that when one object does work on another, the exact amount of energy lost by the first object is transferred to the second. This means the total energy remains constant; the total energy before any work is done is equal to the total energy after. Although energy conservation might not always be visible at the macroscopic level, (e.g., some of the energy is converted to heat, or multiple objects and fluids are involved), the total energy always remains the same.

The conservation of energy can be used to infer, for example, the minimum amount of energy that was contained by the gunpowder in a cartridge. For example, if both the mass and the muzzle velocity of a bullet are known, the bullet's energy can be calculated. And due to the conservation of energy, it can be inferred that the gunpowder and rifle must have done an equal amount of work on the bullet to transfer energy to it. Therefore, the energy of the gunpowder must have been at least as much as the energy of the bullet.

In fact, to determine the efficiency of energy transfer from the gunpowder to the bullet, one can divide the energy imparted to the bullet by the total chemical energy contained in the gunpowder. The remaining energy not transferred to the bullet is lost as heat, either to the rifle or the surrounding environment.

25.e Momentum

Momentum is a fundamental concept in physics that describes the motion of an object in terms of its mass and velocity. It's a vector quantity, meaning it has both an amount and a direction. The formula for momentum is:

- $Momentum = (Velocity \times Mass)$

These same variables can be converted to be expressed in a different way:

- $Momentum = (Force \times Time)$

Momentum is most often calculated to employ a property of matter called the "principle of conservation of momentum." In physics, the term conservation refers to something which doesn't change. This means that the variable in an equation which represents a conserved quantity is constant over time. It has the same value both before and after an event. So "conservation of momentum means that two objects, without external interference, always have the same total amount of momentum between them, even if one gives momentum to the other.

This principle is very helpful in making certain conclusions. For example, if one object changes momentum, it can be deduced that another object has also changed momentum. Also, because momentum has a direction component, if one object changes direction, it can be deduced that another object also changed direction. In those regards, momentum is related to Newton's third law of motion, which states that any force exerted on one object (over time) requires another object to have also experienced the same force (over time) but in the opposite direction.

The conservation of momentum is evident on a pool table, where the cue ball transfers momentum and energy to the target ball. If the cue ball comes to a complete stop, the momentum of the cue ball before the collision must equal the momentum transferred to the target ball after the collision (excluding friction from the surface of the table).

In that vein, momentum is useful in explaining the concept of recoil. Due to the conservation of momentum, moving a bullet forward at a faster speed also causes the rifle stock to move backward faster. Likewise, moving a bullet with more mass forward also leads to a faster backward movement of the rifle stock.

26. Functions and Malfunctions

A rifle is a machine that translates human input (e.g., pulling a trigger) to mechanical output (e.g., releasing the firing pin). To achieve this, rifles perform a series of functions. The specific steps can vary depending on the rifle's mechanism, as some steps are a matter of preference. However, military rifles generally follow a common list of functions: 1) feeding, 2) chambering, 3) locking, 4) firing, 5) unlocking, 6) extracting, 7) ejecting, and 8) cocking. The following subsections start with feeding because feeding is a firing cycle's starting point when starting with an unloaded rifle. However, since functions do occur in a cycle, any function could technically act as the cycle's starting point.

Since a rifle has a limited number of functions, it can only have a limited number of malfunctions. When attempting to repair a broken rifle, the best initial step is to identify which function is not working correctly. However, this can be challenging as malfunctions often occur simultaneously or commonly cause other malfunctions. Additionally, some malfunctions can be fixed

New and Used Primers

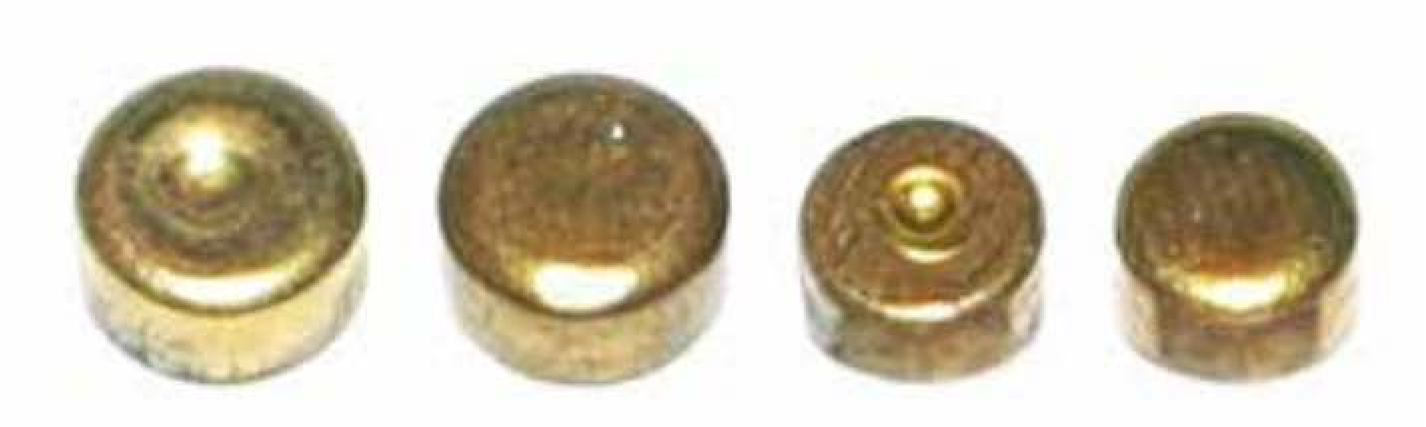

Image 202: Used primers have divots in them (left). New primers are flat (right). If any sort of divot is present on a live round, then it must be considered a dangerous explosive, since the divot indicates that the primer has already been struck, making it unknown whether the primer is unstable and spontaneously explosive.

immediately using the solutions provided here. However, if a malfunction is caused by broken or defective rifle parts, the marksman may need to consult a gunsmith for repairs.

26.a Feeding

Feeding is the process of positioning a cartridge centrally within the bolt channel (See Image 4, Pg. 16.). In a bolt-action rifle, this involves manually inserting a round or pushing the bolt forward. In a semi-automatic rifle, the first round is typically fed by locking the bolt to the rear, loading a round, and releasing the bolt, with subsequent feeding being automatic.

A common malfunction, a failure-to-feed, occurs when a round fails to enter the action. The most common cause of a failure-to-feed is a worn or damaged magazine, and the failure can be resolved by reseating or cleaning the magazine. However ideally, the magazine is replaced whenever there is a failure-to-feed. If the magazine is not the cause of the malfunction, then alternatively, the action may require cleaning and lubrication. However, marksmen must avoid over-lubricating, as it can attract dirt and cause problems in cold conditions. Other potential issues include a weak or broken mainspring and a bolt that binds in the receiver.

During shooting, a failure-to-feed often goes unnoticed by the marksman, who may mistakenly believe that a round is in the chamber. In such cases, a failure-to-feed is indistinguishable from a failure-to-fire. To avoid injury, marksmen must wait for 30 seconds and keep the rifle pointed in a safe direction before attempting to open the bolt, as the primer may have been struck and could have a delayed reaction (a.k.a., a "hang fire").

26.b Chambering

Chambering involves moving a cartridge from its centrally aligned position within the bolt channel to being fully seated in the firing chamber. (See Image 4, Pg. 16.) Feeding and chambering rely on different mechanical parts and can be differentiated by checking for specific failures.

A failure-to-feed indicates that there is no force pushing a round into the chamber, whereas a failure-to-chamber means that a cartridge cannot enter the chamber. A failure-to-chamber may occur if the cartridge itself is damaged, so it is crucial to first inspect and safely discard any damaged cartridges before any shooting session. Additionally, a dirty chamber can cause problems, so it must also be inspected and, if needed, cleared and cleaned before use. Other issues that can arise include a weak or broken mainspring or a bent receiver housing. Repairing or replacing components may require the assistance of a qualified gunsmith.

26.c Locking

Locking refers to the immobilization of the action and sealing of the chamber, preventing any explosive gases from escaping out the back of the rifle. While feeding and chambering require pushing the bolt, locking generally involves a rotation of the bolt and engages separate mechanical parts such as a bolt latch and bolt latch trip, or a bolt and a star chamber.

Issues related to locking or unlocking may arise due to an internal obstruction between the firing pin and the bolt. This is because many actions have a safety mechanism which requires the firing pin to rotate to engage in a locked chamber and enable firing. To fix a firing pin obstruction, a marksman may have to disassemble and clean the rifle bolt. Bolts contain springs and small parts, and so this exercise must always be done in an area where dropped parts can be found (e.g., above a flat floor without gaps.)

That being said, locking and unlocking problems may be caused by root issues such as: a blown or wedged primer; a broken or burred bolt latch; a broken bolt-latch spring; or a bent or improperly seated bolt-spring. All of these issues all best addressed by an expert gunsmith.

An improper lock may also be caused if a marksman rests the rifle on its magazine. In this case, the marksman only needs to adjust their rifle hold to take pressure off of the magazine.

26.d Firing

Firing as a function of a rifle encompasses the steps that cause the release of the sear (part of the trigger assembly), thereby causing the firing pin to strike the primer on a cartridge. Firing is completed when the pressure within the barrel and chamber returns to a neutral state.

Failure-to-fire may occur due to faulty ammunition. Specifically, sometimes the firing pin correctly strikes a primer, but the primer fails to ignite. If this happens, a marksman must inspect and potentially replace all of the ammunition from the same manufacturing lot. (See Image 202, Pg. 248.)

It is also possible that the firing pin or spring itself is faulty or defective. This can be identified by a shallow impression or no impression on the primer after firing. Any defective firing pin, firing mechanism, or trigger components requires the expertise of a gunsmith.

In cases where the primer was struck, but nothing happens, marksmen must wait 30 seconds while keeping the rifle pointed in a safe direction before attempting to open the bolt. This prevents a delayed reaction from causing an injury. Similarly, when unloading, the ejection port must also be pointed in a safe direction in expectation of a delayed reaction. Once the round is ejected, the marksman can inspect the primer. If it was struck, then the ammunition was the cause; if it was not struck, then the rifle was the cause. Regardless, marksmen must never attempt to reuse a round that failed to fire.

During this phase, there can be overly-strong recoil, which must not be confused with a failure-to-fire. Hard recoil may be caused by faulty or heated ammunition, which must be replaced or allowed to cool. (See Temperature, Pg. 188.) Damage to the mainspring, mainspring buffer, or muzzle break can also contribute to this issue, necessitating the replacement of the damaged components by an expert.

26.e Unlocking

Unlocking, the next function or phase in the rifle's cycle, refers to the reversal of the immobilization of the action that occurred during the locking step, allowing the spent cartridge to be extracted. Unlocking failures occur for the same reasons as locking failures. (See Locking, Pg. 249.)

26.f Extraction

Extraction is the process of moving the spent case from the chamber into the action of the firearm. It is the opposite function of chambering, however, it

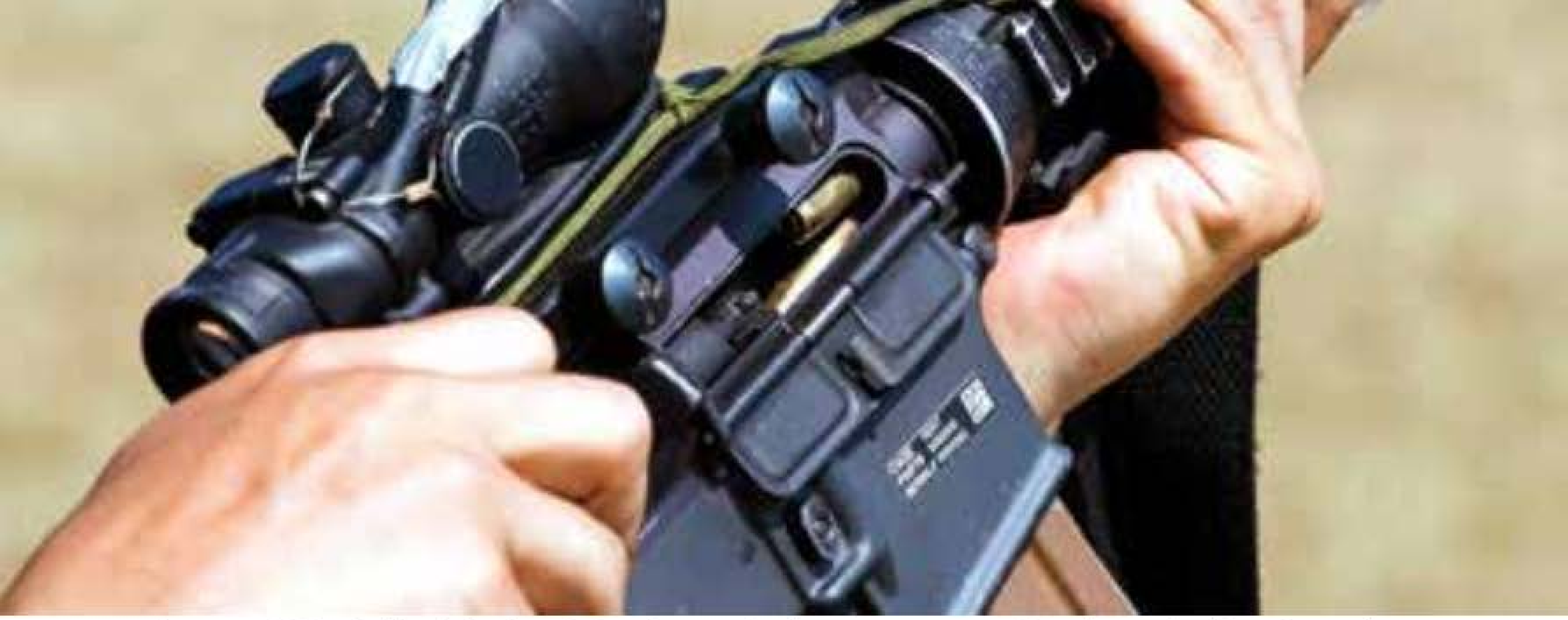

Image 203: A **double feed** is when a bolt attempts to feed two bullets into the chamber at the same time. This is caused by a **failure-to-extract** a previous bullet from the rifle. The extractor can fail to extract if it is broken, but more often the magazine is old or being mishandled, or the gun may lack proper lubrication.

may use a different mechanism in the rifle (e.g., the extractor). Any extraction failures can occur if the extractor is not moving freely in its slot. In that case, the extractor is broken or stuck and it must be removed and cleaned or completely replaced with a new one. However, another common cause of extraction failure is bad or mishandled magazines. Preventing double feeds is a primary reason marksmen do not rest rifles on their magazines.

Extraction failure is usually detected when attempting to chamber another round, resulting in a double feed and a failure-to-chamber. To clear a stuck casing in the extraction port, a marksman can pull it out with pliers. To clear a stuck casing in the chamber, a marksman can push it out by inserting a cleaning rod into the muzzle and pushing it down into the stuck casing.

If there is a failure-to-fire and an extraction failure, meaning the stuck round is live, a marksman must wait 30 seconds to ensure the round does not spontaneously explode. Then the marksman can remove the bolt, thereby rendering the rifle incapable of firing, and take the rifle to a gunsmith, who can safely remove the stuck, live round. Although there is no risk of explosion by slowly and carefully pushing on a bullet if the ammunition is good, stuck ammunition is by definition bad ammunition. And this manual cannot recommend that an amateur forcefully push on a live round with a metal rod.

26.g Ejection

Ejection as a function of a rifle is the removal of the spent casing from the firearm's action to outside the firearm. A failure-to-eject occurs when a cartridge remains partially in the chamber or becomes jammed in the upper receiver. One type of failure-to-eject is typically referred to as a "stovepipe," and happens when a spent cartridge casing gets stuck in the ejection port. (See Image 204, Pg. 253.) Stovepipes can usually be fixed with standard malfunction actions. (See Standard Malfunction Actions, Pg. 252.) A failure-to-eject could also be caused by a frozen or damaged extractor, ejector, or ejector spring. Often, failures-to-eject are due to friction from dirt or carbon buildup. In semi-automatic rifles, a "fouled" (i.e., has carbon build-up) gas tube can restrict the flow of gas and prevent sufficient force from reaching the extraction and ejection mechanism. These malfunctions that are caused by problematic rifle parts require expert attention to fix.

26.h Cocking

Cocking is the setting and resetting of stored energy within the firearm to allow the firing pin to launch forward once the sear is disengaged by pulling the trigger. Cocking can be caused, for example, by the manual rearward pulling of the bolt in a bolt-action rifle or by the force of redirected gases in a semi-automatic rifle. Cocking failure is likely caused by worn, broken, or missing components of the trigger assembly and sear assembly. A cocking malfunction requires expert attention.

26.i Standard Malfunction Actions

If a rifle stops working during any function, a marksman can save a lot of time by performing a few quick actions that immediately fix most malfunctions. The specific actions depend on the rifle. However, all fixes begin with ensuring that the weapon is pointed in a safe direction and the safety mechanism is activated.

When a standard bolt-action rifle malfunctions, a marksman can:

1) Remove the ammunition source to prevent further feeding.

2) Pull the bolt back to its rear position to address any potential malfunction caused by a stuck or misaligned round.

3) Complete two full cycles of the bolt, ensuring that it moves smoothly, and then leave it in the open position.

4) Reinsert the ammunition source, chamber a round, and attempt to fire

To fix a standard semi-automatic rifle, marksmen first attempt "immediate action," which is a quick procedure to try and get the weapon back into

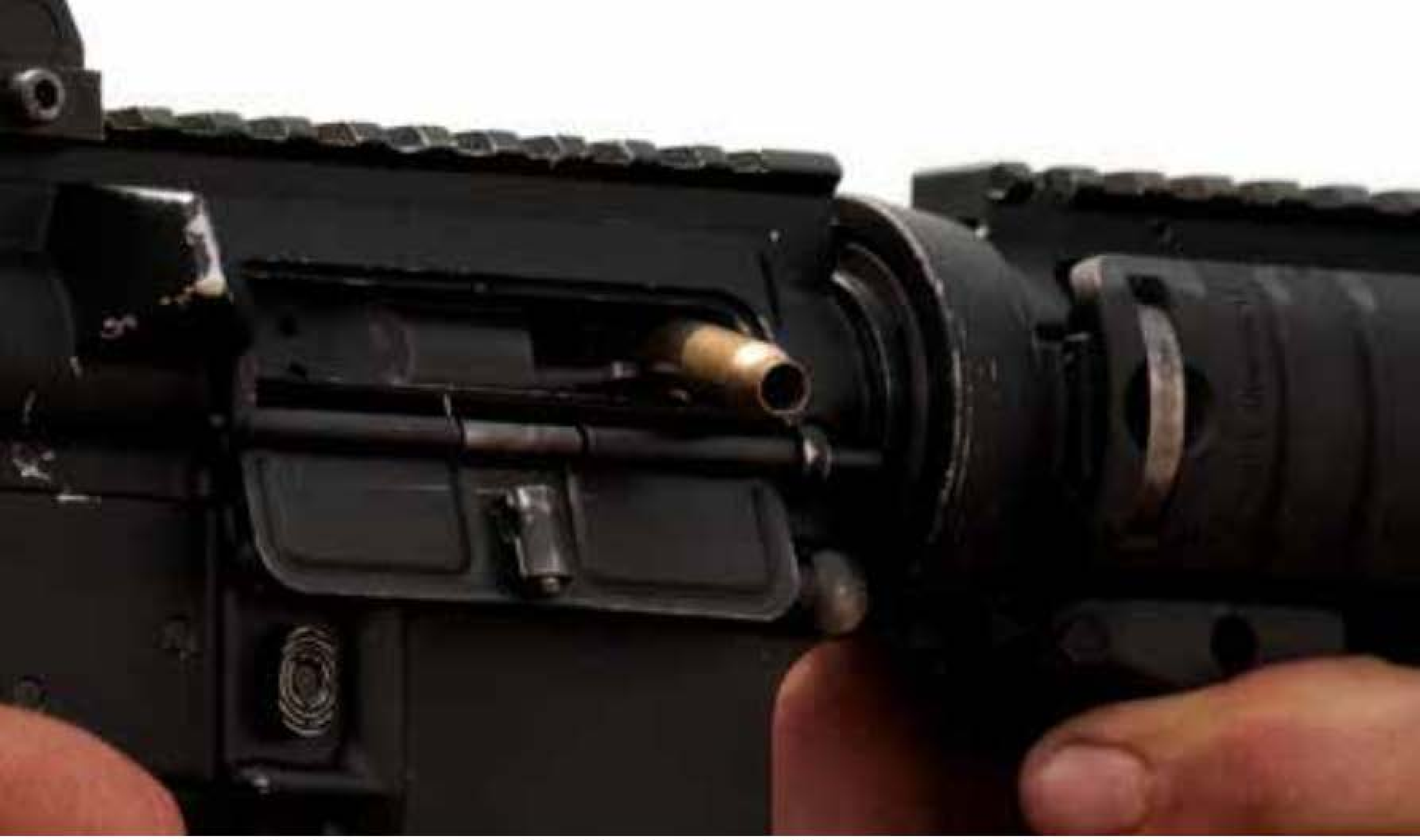

Image 204: A **stovepipe** malfunction is a type of firearm malfunction where a spent casing fails to eject properly and gets caught in the ejection port of the firearm. The casing typically sticks out of the ejection port, resembling a "stovepipe," hence the name. Stovepipe malfunctions can occur due to a clogged gas port that blocks gas from operating the ejector, a fault ejection mechanism, or weak gunpowder.

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operation without diagnosing the problem in detail. This is often referred to by the acronym SPORTS:

Slap – the bottom of the magazine to ensure that it is properly seated.
Pull – the charging handle to the rear.
Observe – the ejection port to check for any ejection or obstruction.
Release – the charging handle to allow the bolt to go forward.
Tap – the forward assist (if there is one) to ensure the bolt is locked.
Squeeze – the trigger to attempt firing.

If immediate action fails, a marksman can attempt "remedial action" to correct the malfunction:

1) Reattempt immediate action. If it still fails, proceed to the next steps.
2) Remove the source of feed (e.g., the magazine).
3) Lock the bolt to the rear.
4) Clear the weapon by visually inspecting the chamber, magazine well, and bolt, and remove any obstruction or jammed cartridge.
5) Reinsert the ammunition source, chamber a round, and attempt to fire.

27. Glossary

Accuracy	The degree to which shots are centered on the point-of-aim.
Action	The part of a gun that moves cartridges in and out of position.
Adjustable objective dial	A parallax adjustment dial located on the scope's objective bell (i.e., it's far side).
Aerodynamic	Relating to how air moves around objects, and how objects move within the air.
Air density	How thick the air is. Influenced by station pressure, temperature, and humidity.
Ambidextrous	Capable of using both hands with equal skill.
Ammunition (Ammo)	The projectiles and propellant (a.k.a., gunpowder) used in firearms.
Angle cosine indicator	Device mounted on a rifle to measure and adjust for shooting angles.
Angular distance	Angular measurement between two points.
Angular height	Measurement of an object's apparent height in angular distance units.
Aperture	A small opening that is used for looking through.
Arc	A curved path of travel
Auxiliary	Additional or supplementary components or equipment.
Ballistic calculator	A device that calculates bullet trajectories based on factors such as distance, wind, and temperature.
Ballistic coefficient	A measure of a bullet's aerodynamic drag in the air. Bullets with higher ballistic coefficients resist drag better than a bullet with low BC.
Ballistics	Study of the behavior of projectiles, including trajectory, penetration, and impact.
Barrel crown	The point at which the bore meets the outside. The final point of the bore that touches the bullet.
Barrel	The long, narrow part of a gun that the bullet or projectile travels through when fired.
Benchrest	A steady support for a rifle, usually including a bench or table. Also a type of shooting competition that uses said support.
Bipod	A two-legged support attached to the front of a rifle, allowing for increased stability. The legs are often collapsible and adjustable for varying heights.
Bolt	A part in a firearm that moves behind the chamber and seals the rear of the chamber during firing.
Bolt-action	A type of manually-reloaded firearm for which the marksman operates a bolt to cycle rounds in and out of the chamber.
Bone support	The use of the body's skeletal structure to support the weight of the rifle.
Bore	The internal cavity of a barrel in which bullets travel.
Boreline	The imaginary line that extends from the center of the chamber, straight out of the center of the bore, and on to infinity.
Bore-sighting	Roughly aligning a rifle's bore with the scope's sightline.
Bracket	First, establishing a minimum and maximum to set a range. Then, establishing new minimums and maximums that are closer to the average to make the range smaller.
Brass	Another name for casings, since most casings are made from brass.

Breech	The loading entry point for ammunition. In everyday conversation “breech” and “chamber” could be used interchangeably. Technically, the breech is where the bolt rides, but forward of the ejection port.
Bullet-drop	The vertical, linear distance that a bullet falls due to gravity over distance.
Bullet-drop compensator	A kind of reticle in scopes that spaces hashmarks according to a set increment of linear distance instead of angular distance.
Butt, buttstock	Rear portion of the rifle stock that rests against the marksman’s shoulder, providing support and stability.
Caliber	Internal diameter of a bore, expressed in inches or millimeters.
Cant	A rotation of the rifle or scope off the vertical axis (directly up or down).
Cartridge	A complete unit of ammunition containing a casing, a primer, gunpowder, and a bullet.
Casing, Case	The part of a cartridge that contains the other parts (i.e., the primer, gunpowder, and bullet).
Center average	The vertical and horizontal center of all the points in a grouping.
Centerline of the bore	See boreline.
Chamber	Part of a firearm where the cartridge is inserted and locked into for firing.
Cheek piece	A part of a stock that supports the marksman’s cheek, aiding eye alignment with the sight(s) while firing.
Cheek weld	Proper placement of the marksman’s cheek on the rifle stock for consistent sight alignment.
Centerfire	A type of ammunition where the primer is located in the center of the cartridge base.
Clicks	Units of adjustment for firearm sights, both iron and optical. These sights have rotating turrets that click when adjusted by one increment.
Climate	Characteristics of the air, including density (pressure, temperature, humidity) that affect bullet trajectory.
Cold-bore	Refers to a firearm barrel that hasn’t been recently fired and is therefore cool.
Cone-of-fire	The dispersion pattern of bullets fired from a firearm, where the point of the cone is at the muzzle, and the base is at the target.
Conical	In the shape of a cone.
Cowitness	Using the point-of-aim of one sight on a gun to set the point-of-aim on a second sight on the same gun.
Crosshairs	The horizontal and vertical lines that respectively extend the full width and height on the reticle and intersect in the center.
Crosswind deflection	Deflection due to the portion of the wind’s power that is perpendicular to the trajectory of the bullet.
Crown	The meeting point between a barrel’s muzzle and its bore. The crown can be slightly recessed or relieved to protect the forward edge of the rifling from damage, which can affect accuracy.
Cycle	To operate the action of a firearm.
Deflect	To push an object from one trajectory to another trajectory.
Depth-of-field	Range of distance in which objects appear sharply focused.
Dispersion	The spaced-out pattern of individual points.
DOPE (Data On Previous Engagement) book –	Record book used by marksmen to log specific details of each shooting session for future reference and adjustment.

Double feed	The simultaneous attempted feeding of two or more rounds into a chamber.
Drag	The portion of air resistance that slows a bullet down.
Dry fire	The act of cocking, aiming, and pulling the trigger of an unloaded rifle for the purpose of practicing marksmanship fundamentals.
Duplex reticle	A scope reticle design featuring coarse crosshairs at the outside that narrow down to fine lines at the center.
Eddy	Unpredictable wind patterns, typically created by obstacles such as trees or buildings blocking the wind's forward path causing swirling currents of air.
Ejection	Removal of spent casing from the firearm's action after firing.
Ejection port	Opening on the rifle through which spent cartridges are ejected after firing.
Elevation, Elevation hold	– The vertical measure of a sight or scope in angular measurements.
Environment factors	External conditions such as wind, gravity, and temperature that affect the flight path of a bullet.
Equivalent crosswind	The speed of a hypothetical wind perpendicular to the trajectory of the bullet that acts on the bullet with equal force to the actual wind.
Exponential	The dependent (Y) variable changes faster than the independent (X) variable.
Exterior ballistics	The study and calculations related to factors affecting a bullet's flight after it leaves the barrel.
Extraction	Removal of a spent casing from the chamber into the firearm's bolt channel.
Extractor	A part of a firearm that removes the spent cartridge after firing.
Eye relief	The distance from the ocular lens of the scope to the marksman's eye.
Failure-to-chamber	Cartridge unable to enter the firing chamber.
Failure-to-eject	Spent cartridge not fully ejected from the firearm.
Failure-to-feed	Cartridge fails to enter the action for firing.
Felt-recoil	The subjective force of recoil felt by a marksman. Actual recoil feels different to different people for various reasons.
Fine-tune	To make precise adjustments or modifications.
Firing	Release of firing pin to strike the primer of a cartridge, causing an explosion.
Firing pin	Component in a firearm that strikes the primer of a cartridge to initiate ignition.
Fliers	Outliers in a shot group that deviate significantly from the main pattern.
Flinching	Involuntary movement or reflex.
Focus	To adjust the scope to make the reticle and sight picture sharply visible.
Follow-through	Maintaining focus and technique after firing the shot to ensure accuracy.
Forestock	The front part of a rifle stock. It may or may not connect to the barrel depending on the design of the firearm.
Forward assist	A mechanism on some rifles, such as the AR-15, that is used to ensure proper chambering of a round by pushing the bolt forward.
Functions check	The performance check of each function of a firearm in sequence to ensure a firearm operates properly.
Functions	The mechanical steps that a firearm cycles through to operate.

Gas-operated	Refers to an automatic (i.e., self-loading) firearm that uses the expanding force of the propellant's gas to cycle a weapon's action.
Grime	Dirt or residue that has accumulated and adhered to surfaces of both the inside and the outside of a weapon or object.
Grip, rifle grip	The part of the firearm that the trigger hand holds, and the manner in which the marksman holds that part.
Group, grouping	A series of shots fired with the same point-of-aim. Five-shot groups are standard.
Group size	The size of the spread of impacts in a group. Can be the center average or the diameter.
Gunsmith	Skilled professional specializing in the design, construction, repair, and modification of firearms.
Gust	A sudden and temporary increase in wind speed.
Handguard	See forestock.
Handling	The act of touching or manipulating firearms or ammunition, requiring caution and respect.
Hashmark	A small marking, such as a line or dot, used to indicate distance on a reticle.
Height-above-bore	The vertical distance between the boreline and the sightline where the scope is mounted.
Hold	A vertical or horizontal adjustment in angular units to the rifle that allows the marksman to use a point on the reticle other than the center as their point-of-aim.
Holdover	Either another name for height-over-bore, or the hold used to compensate for it.
Imperial system	The nickname for the United States Customary System, primarily used in the United States and based on inches, feet, pounds, etc.
Inclination	The angle between a straight line and the horizontal plane perpendicular to gravity.
Inferior mirage	Mirage that makes objects appear lower than they are.
Interior ballistics	The study of the forces inside the cartridge and barrel during firing.
Jacketed bullet	Bullet with a metal casing (the jacket) covering the core.
Joists	Horizontal supporting beams in structures, mentioned as a safe direction to point a rifle.
Kentucky windage	An estimated and imprecise aiming adjustment to compensate for wind effect or target motion.
Laser rangefinder	Electronic device using laser technology to precisely measure distance to a target.
Lateral throwoff	Random deviations from the boreline caused by equipment.
Lift	The component of aerodynamic force that causes a bullet to deflect (i.e., move perpendicularly to its direction of travel).
Linear	A change in one variable causes a consistent and constant change in another variable.
Linear average	The center point between the two farthest points in a group.
Linear distance	The straight-line distance between two points.
Line-of-sight	An imaginary line extending from the marksman's eye through the rifle's sights and onto an aiming point on a target.
Locking	Immobilization of the cartridge within the action to prepare for firing.
Loophole	An opening within a barrier that a marksman fires through.
Magazines (Mag)	The part of a rifle that stores ammunition. It may or may not be detachable.
Magazine well	The cavity in a firearm's receiver where a detachable magazine is inserted and held in place.

Magnification	Optical feature on scopes that enlarges target view for precise aiming.
Malfunctions	A failure to perform a function of a firearm's operation.
Mechanical center	Midpoint of a turret's adjustment range on a scope.
Metric system	The nickname for the International System of Units, a decimal system of measurement based on meters, liters, kilograms, etc.
Mil, mils	See milliradians.
Milliradians (mils)	A unit of angular measurement. Depending on the definition, there are between 6,000 and 6,400 milliradians in a circle.
Mildot reticle	A crosshair design with circular (dot) hashmarks along its crosshairs.
Milling	Measuring the angular height of an object in mils or MOA through a reticle to calculate the distance to that target.
Minute, Minute-of-angle (MOA) –	A unit of angular measurement. Usually a minute is 1/60 of a degree. There are 360 degrees in a circle. A different definition has ~22,620 MOA in a circle.
Mirage	A wavy optical distortion caused by variations in air pressure that cause light to move through the air in slightly different directions.
Muzzle	The barrel's end, from which the bullet exits upon firing.
Muzzle jump	Upward movement of the firearm's muzzle upon firing.
Muzzle velocity	The speed at which a bullet leaves the muzzle of the firearm.
Natural point-of-aim (NPA) –	Position where the rifle aligns naturally when the marksman is relaxed.
Objective lens	The lens at the front of a scope.
Ocular lens	The lens of a scope closest to the marksman's eye.
Optics	Devices related to light and lenses, including scopes and rangefinders.
Parallax	The apparent shift in the position of the reticle or sights relative to the target when the marksman's eye moves.
Pinwheel	A small rotating propeller that uses the power of the wind to rotate.
Plumb	Aligned to gravity.
Plumb line	A string with a freely hanging weight attached to and pulling on the bottom that is perfectly aligned to gravity.
Point-blank range	Distance from the muzzle at which a firearm can hit a target of a specified height without adjusting the aim to compensate for bullet-drop.
Point-of-aim	The exact location a marksman intends to hit on a target, and the location on a reticle they use to aim at that location
Point-of-impact	Where the bullet strikes the target.
Power	Power can refer to either the energy of the bullet or the magnification level of the scope sight.
Precision	The degree to which shots cluster closely together, indicating consistency and control.
Probabilistic shooting	Concept acknowledging that every shot has inherent random factors affecting trajectory, resulting in a dispersion pattern rather than a single trajectory.
Projectile	An object propelled through the air, such as a bullet or artillery shell.
Range	The distance between two points.
Range, Shooting range –	A designated place where live-fire weapons training is conducted.
Rangefinder	Device used to measure the distance to a target.
Recoil	Backward movement of the firearm caused by the explosion of gunpowder.

Repeatable	The concept that an adjustment in one direction exactly equals an adjustment in the opposite direction.
Rest	A support for the rifle that a rifle can sit in, supporting both the front and the back of the rifle. Rests can range from specially-designed devices to sandbags or improvised supports.
Reticle	A pattern of crosshairs and hashmarks in a scope that is used for aiming and finding angular measurements.
Rifle system	The set of equipment that allows a projectile to impact at the marksman's point-of-aim, including a rifle, optics, ammunition, and auxiliary equipment.
Rifling	The grooves cut into the barrel's bore that induce a spinning motion to the bullet, improving its stability during flight.
Rimfire	A type of ammunition where the primer is located within the rim (i.e., side) of the cartridge base.
Round	See cartridge.
Safety	Mechanism on firearms to prevent the firing pin from striking the primer and causing ignition or the cartridge.
Safety selector	Mechanism on a firearm that activates or deactivates the safety.
Sandsock	A fabric bag (e.g., a sock) filled with a grain (e.g., sand or pellets) used as a shooting support to stabilize a firearm.
Scope, riflescope	An optical sight that uses lenses to enable a marksman to see a magnified sight picture without parallax.
Scope adjustment	Fine-tuning the scope's turrets to adjust the reticle's location within the scope and thereby change the reticle's point-of-aim.
Scope mount	Device to attach a scope to a rifle.
Scope tube	Outer housing containing the lenses.
Semi-automatic	Firearm (or the action therein) which fires one round per trigger pull, automatically chambering the next round.
Shooting positions	Various body positions used for shooting, including prone, kneeling, and standing.
Side focus turret	Turret on the left side of a scope that adjusts for parallax and target focus.
Sight	A device that a marksman uses to aim.
Sightline	See line-of-sight.
Sight picture	The view that a marksman sees when the point-of-aim is aligned to the point-of-impact. For a scope, it is the image seen through the scope.
Silencer	A common term for a "suppressor," a device designed to reduce the noise of a gunshot.
Simple mirage	See mirage.
Slack	The distance that a trigger can be pulled before it engages the sear and discharges the firearm.
Sling	A long strip of fabric or leather that connects the forestock to the marksman's upper arm, allowing the marksman to aim more precisely.
Spotter	A partner to a marksman who feeds the marksman information on the situation, target, and optimal holds.
Station pressure	Actual air pressure at a specific location and elevation.
Stock, Rifle stock	Bottom part of the rifle that the marksman holds, including the buttstock and forestock.
Stock weld	See cheek weld.
Strap	A long strip of fabric or leather attached to a firearm that allows it to be carried. It is not useful for aiming.

Streamer flags, Streamers	– Simple strips of cloth or plastic, often brightly colored, that flutter and thereby show wind direction.
Sub-MOA	The capability of a rifle to consistently shoot groups with a diameter of less than 1 MOA in diameter.
Subtension	The distance between two hashmarks.
Superior mirage	Mirage where that makes objects appear higher than they are.
Supersonic	Any speed that is faster than the speed of sound.
Support	An inanimate object that helps to support the weight of a rifle.
Suppressor	Device attached to a muzzle to reduce the noise and recoil of the firearm.
Target focus	Whether the target can be seen clearly or is blurry.
Target identification	Recognizing and identifying specific targets for accurate shooting.
Terminal ballistics	The study of a projectile's behavior upon impact with a target, including penetration, expansion, and energy transfer.
Trajectory	The curved path followed by a projectile in flight, affected by factors such as gravity and wind.
Trigger control	Technique of smoothly pulling the trigger to avoid disturbing aim.
Trigger finger	The finger used by the marksman to pull the trigger, usually the index finger.
Trigger group, Trigger assembly	– The complete set of components within a firearm that includes the trigger, sear, and other parts that cause a firing pin to suddenly strike the primer and fire the rifle.
Trigger guard	A loop or enclosure that surrounds the trigger, protecting it from negligent discharge or external interference.
Turret	A rotating mechanism that adjusts part of the rifle incrementally. Each incremental turn makes a click.
Turret cap	A cover that protects the adjustment turrets on a riflescope.
Unload	To remove ammunition from the chamber or magazine of a firearm, ensuring it's not ready to fire.
Vane	A horizontal stick with a tail and pointer mounted on a vertical pivot, where the tail catches the wind to direct the pointer into the direction of the wind.
Weathervaning	Bullet aligning with incoming wind direction due to spin stabilization, akin to how a weathervane aligns with the wind.
Wind reading	Assessing wind speed and direction to adjust aim and ensure accurate shots.
Windsock	Cone-shaped fabric tubes inflating at specific speeds to indicate wind direction and intensity.
Wind value	Fractional representation of the equivalent crosswind component relative to the bullet's trajectory angle.
Windage	The horizontal adjustment to the aim of the firearm to compensate for wind drift.
Windage turret	The turret on a scope that allows for horizontal reticle alignment.
Zero	The alignment of the scope's point-of-aim with the bullet's point-of-impact at a specific distance for a specific rifle and scope.
Zero distance	The specific range at which a rifle and its scope are set to hit the target where the center of the reticle points.
Zero point	The two points at which the sightline intersects the trajectory of the bullet.
Zero stop	A lock that can be set to prevent a scope turret from turning into negative elevation (i.e., the minimum turn sets the reticle to its zero).

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